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THE
STRUCTURE AND COMPOSITION
OF FOODS

THE STRUCTURE AND COMPOSITION OF FOODS

BY

ANDREW L. WINTON

AND

KATE BARBER WINTON

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In Preparation

THE
STRUCTURE AND COMPOSITION
OF FOODS

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Volume II

VEGETABLES, LEGUMES, FRUITS

CENTRAL FOOD TECHNOLOGI
No.
Date
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WITH 303 ILLUSTRATIONS
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PREFACE TO VOLUME II

THE chemical sections of this volume, in addition to typical conventional analyses, record epoch-making discoveries, largely recent, on the occurrence and constitution of lesser-known constituents such as organic acids, pectins, natural flavors, colors (notably chlorophyl, carotenoids, lyochromes, and anthocyanins), the chemical substances classed as vitamins, and minor mineral constituents. Complete unanimity of conclusions on certain points can hardly be expected; nevertheless, the matter available, on the whole, fills with remarkable completeness the gaps in the literature.

Although vitamins, as unidentified substances classified alphabetically according to their physiological action, are beyond the province of this work, as chemical individuals they call for the same treatment as the long-known constituents.

The sections with illustrations on microscopic structure represent the authors' original work, in large part here recorded for the first time.

A. L. W.
K. B. W.

WILTON, CONN.,
July 1st, 1935.

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STRUCTURE AND COMPOSITION OF FOODS

STRUCTURE AND COMPOSITION OF FOODS

INTRODUCTION TO VOLUME II

THE following pages are designed to cover the salient chemical features common to the two parts of this volume, Vegetables and Fruits, supplementing the brief statements made in the Introduction to Volume I. In a few introductory paragraphs of Parts I and II certain features peculiar to each part are briefly stated.

Proteins.—Dried ripe leguminous seeds, even those of the starchy type, are rich in proteins, notably the globulins. All succulent vegetables, when fresh, are low in nitrogenous constituents by reason of dilution. On the dry basis they differ according to the group, leaf vegetables being high in nitrogen, root and tuber vegetables low. The pulp of fruits free from seeds is even more deficient in nitrogen than vegetables. The high content of amide and amino-acid nitrogen in both vegetables and fruits reduces markedly their content of pure protein.

Amino acids, especially the dextro and levo forms of *asparagine* and *glutamine* or glutamic (glutaminic) acid, $COOH \cdot CH_2 \cdot CH_2 \cdot CH(NH_2) \cdot COOH$, occur in sprouting seeds and green shoots. *Betaine* is present in beet juice (which see) and beet molasses.

Asparagine or α-aminosuccinamic acid, $CONH_2 \cdot CH_2 \cdot CH(NH_2) \cdot COOH + H_2O$, the amide of aspartic (asparaginic or aminosuccinic) acid, $COOH \cdot CH_2 \cdot CH(NH_2) \cdot COOH$, occurs in many leaf and stem vegetables, unripe leguminous seeds, and certain fleshy roots. It is regarded as one of the principal intermediate products between inorganic nitrogenous compounds, such as nitrates and nitrites, and vegetable proteins but lacks the nutritive value of the latter.

l-Asparagine, the common form, is levorotatory in an aqueous alkaline solution and dextrorotatory in an acid solution. It forms rhombic crystals melting at 226 to 230° C., readily soluble in hot water, less so in cold water, and insoluble in alcohol and ether. It is tasteless, whereas *d*-asparagine has a sweetish taste. There is also an inactive form.

Fat, as a noticeable constituent, is limited largely to oily seeds, its presence in the fruit flesh of the avocado being an exception. The ether extract of many vegetables and some fruits is largely *chlorophyl. Volatile oils* occurring in small amount are usually recognized by their odor. Special studies have been made of the surface *wax* of certain fruits and vegetables.

Acids.—Divergent ideas on the nature of the acids in fruits were formerly current; however, during recent years, methods have been perfected that have led to quite definite conclusions as to the principal acids of the common fruits, although in varieties of some species there appears to be some difference in the acids present. The proportion and to some extent the nature of the acids change during growth and ripening, but the general rule that acidity of fruits diminishes during ripening appears to be well established, which, together with the increase in sugars, explains in part the improvement in flavor.

The following statements as to the principal acids are tentative:

Malic, $COOH \cdot CH_2 \cdot CHOH \cdot COOH$, usually levorotatory form: apple, quince, European plum, cherry, barberry.
Citric, $COOH \cdot CH_2 \cdot C(OH)(COOH) \cdot CH_2 \cdot COOH$: pomegranate, fig.
Tartaric, $COOH \cdot CHOH \cdot CHOH \cdot COOH$, usually dextrorotatory form: tamarind.
Citric and Malic: citrous fruits, pineapple, pear, peach, apricot, strawberry, raspberry, blackberry, loganberry, red currant, gooseberry.
Citric, Malic, and Benzoic, $C_6H_5 \cdot COOH$: cranberry, blueberry.
Malic and Tartaric: grape.
Oxalic, $COOH \cdot COOH$: bilimbi, carambola.

There may also be present in small amount succinic acid, $COOH \cdot CH_2 \cdot CH_2 \cdot COOH$, and acetic acid, CH_3COOH. Minute amounts of salicylic acid, $C_6H_4(OH)COOH$, have been found in grapes, strawberries, and other fruits, hence the detection of traces of this acid should not be interpreted as indicating its addition as a preservative.

Oxalic acid occurs as calcium oxalate in many fruits. It is most abundant, as shown by Niethammer,[1] during the earlier stages of growth but in the ripe fresh fruit, according to Arbenz,[2] seldom exceeds 0.03 per cent. Goudswaard [3] has determined the soluble oxalate content in 50 vegetables. Oxalic acid is believed to exist free to some extent in rhubarb, bilimbi, carambola, and some other sour fruits and leaf vegetables, but the evidence is inconclusive.

Nuccorini [4] states that the kind of acid present influences the rate of ripening. When the chief acid is malic the ripening proceeds more rapidly than when it is citric or tartaric. In view of the close relation of the aliphatic acids commonly present in fruit it is not surprising that two or more acids occur in varying amount in the same fruit and that varieties of the same species may not agree fully as to the acid present.

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[1] Z. Unters. Lebens. 1931, **61**, 103.

[2] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[3] Pharm. Weekbl. 1934, **71**, 114.

[4] Boll. ist. super. agr. Pisa 1929, **5**, 453.

Carbohydrates.—Much study has been devoted to the starch of leguminous seeds, tubers, and other subterranean organs, the sucrose of the sugar beet, the inulin of composite roots, and the total reducing sugars of various fruits; little, however, is known of the carbohydrates that form a large part of the nitrogen-free extract and fiber of many fruits and vegetables.

Pectins.—The gelatinizing constituent of fruits and the mother substance in various cellular tissues, such as sugar-beet pomace, apple pomace, and citrus albedo, from which commercial jellying preparations are made, have been studied for over a century.

Braconnot [1] gave the name *pectin* to the acid substance extracted by heating with dilute alkali the marc of starchy roots (previously freed from sugar by washing with water and from starch by boiling with dilute acid) and precipitated with hydrochloric acid. Chodnew [2] and Frémy [3] adopted the name *pectic acid*, reserving the name pectin for the substance which the alkali converts into a salt of pectic acid. Herzfeld [4] disclosed the presence of araban and galactan in the complex, later authors that of galacturonic acid.

Schryver and Haynes,[5] by extracting the marc of apples, strawberries, rhubarb, and turnips with warm 0.5 per cent ammonium oxalate and precipitating with alcohol, obtained an acid substance, *pectinogen* (pectin of other authors). Pectinogen in solution was converted by alkalies at room temperature into pectin (pectic acid of other authors), $C_{17}H_{24}O_{16}$, which was precipitated by concentrated hydrochloric acid. Clayson, Norris, and Schryver [6] confirmed the discovery of Von Fellenberg [7] that an alkaline solution eliminates the methyl group from the insoluble pectic substance of the cell walls and extracts the pectin (" cytopectic acid "), also small amounts of hemicellulose (" cytopentans "), after which the pectin may be extracted by ammonium oxalate. Norris and Schryver [8] consider that pectin consists of 1 galactose, 1 arabinose, and 4 galacturonic acid groups and that pectinogen has in addition a methyl group and is in combination with calcium and other bases. In the pectin (pectinogen) of orange albedo Ehrlich and Kosmahly, in addition to 1 galactose and 1 arabinose, found 4 galacturonic acid, 2 acetyl, and 2 methyl groups, and Myers and Baker found 8 galacturonic acid, 2 acetyl, and 7 methyl groups.

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[1] Ann. chim. phys. 1825, [2], **28**, 173.

[2] Ann. 1844, **51**, 355.

[3] J. pharm. chim. 1840, [2], **26**, 368; 1847, [3], **12**, 13.

[4] Z. Ver. Zucker-Ind. 1891, **41**, 295, 667.

[5] Biochem. J. 1916, **10**, 539.

[6] Ibid. 1921, **15**, 6, 653.

[7] Biochem. Z. 1918, **85**, 45, 118.

[8] Biochem. J. 1925, **19**, 676.

Ehrlich and Kosmahly assign to orange pectin the formula $C_{41}H_{60}O_{36}$ and Myers and Baker $C_{70}H_{98}O_{58}$, the groups being as given above (see Orange). Sugar beet pectin, according to Ehrlich and Sommerfeld, has the formula $C_{43}H_{62}O_{37}$, differing from that of orange pectin in having 3 acetyl groups.

Pectic Enzymes.—Bertrand and Mallévre[1] showed that pectase converts pectin in alkaline solution into pectic acid. Bourquellot and Hérissey[2] discovered in malt *pectinase*, that dissolves pectin, and *pectase*, that coagulates it, probably as pectic acid. Ehrlich[3] hydrolyzed pectin by pectolase, occurring in taka-diastase, the mycelium of *Penicillium glaucum*, molds of the *Perisporiaceæ*, and the snail *Helix pomatia*. The first insoluble product of the hydrolysis is stated to be pectolic acid ($C_{24}H_{34}O_{25}$) which is the real pectin nucleus, containing 4 galacturonic acid equivalents, that passes, by breaking the ring, first into pectolactonic acid ($C_{24}H_{32}O_{24}$) and finally into 4 molecules of *d*-galacturonic acid ($C_6H_{10}O_7$).

Histology.—Of particular interest is the work of Mangin,[4] who definitely located the seat of pectin as being in the middle lamella of the cell wall and showed that various dyes differentiate it from cellulose and lignin, the color formed by safranin being yellow-orange.

The work of Carré is reviewed under Apple (Microscopic Structure and Changes in Composition During Storage).

Tannins.—Aside from acids, sugar, and odorous constituents such as esters of organic acids, the flavor of the apple, pear, quince, and certain other fruits is due in considerable part to tannin and other astringents. Apples containing a reasonable amount of astringents are well suited for cider.

Phosphorus-Organic Compounds.—Only in the case of leguminous seeds have these substances received considerable attention.

Colors.—Both vegetables and fruits contain colors of at least five groups: (1) *chlorophyls*, (2) *carotenoids*, (3) *flavones* and *flavonols*, (4) *lyochromes* or *flavins*, and (5) *anthocyanins*.

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[1] Compt. rend. 1894, **119**, 1012; 1895, **120**, 110; 1895, **121**, 726.

[2] J. pharm. chim. 1898, [6], **7**, 473; 1898, [6], **8**, 145; 1899, [6], **9**, 281.

[3] Cellulosechem. 1930, **11**, 140, 161; Biochem. Z. 1932, **250**, 525.

[4] Compt. rend. 1888, **107**, 144; 1889, **109**, 579; 1890, **110**, 295; 1893, **116**, 653; J. Bot. 1891, **5**, 400; 1892, **6**, 12, 206, 235, 363; 1893, **7**, 37, 121, 325.

Chlorophyls are present in all green parts of vegetables grown in the sunlight, associated with the *carotenoids*. All fresh leaves, according to Willstätter and Stoll,[1] contain about as follows: chlorophyl *a* 0.200, chlorophyl *b* 0.075, carotenes 0.017, and xanthophyls 0.033 per cent.

The function in photosynthesis of the green coloring matter of leaves attracted the attention of early physiological botanists. When it was discovered that the carbon of plants is derived in the sunlight from the carbon dioxide of the air with the liberation of oxygen, that the exchange of gases takes place through the stomata, and that chlorophyl grains are always present in the tissues beneath the stomata, it was a natural assumption that chlorophyl in some manner takes part in the reaction. Years of research have as yet failed to determine whether chlorophyl is essential in photosynthesis or is an inactive bystander. Certain it is that neither does chlorophyl appear nor does photosynthesis take place except in the sunlight, and that lower and higher vegetable forms without chlorophyl, even when growing in the sunlight, are incapable of utilizing atmospheric carbon dioxide.

Illustrative of the lack of uniformity in theories as to the role played by chlorophyl are papers by two investigators. One, Mazé,[2] states that he was unable to find evidence that chlorophyl takes any direct part in the chemical changes during photosynthesis; the other, Ewart,[3] believes that chlorophyl is active in the chemical reaction, chlorophyl and related substances, also carotenoids, being transition products, and carbohydrates, formaldehyde, and oxygen end products.

The chlorophyl grain appears to be made up of stroma or a sponge-like mass, consisting of protein matter, in the interstices of which are deposited the chlorophyls and carotenoids, also carbohydrates and probably other substances.

Physiological botanists in early experiments found that plants did not develop a green color if grown in a nutrient solution containing no iron. Verdeil,[4] who first brought out a relationship of chlorophyl to the hemin of blood, assumed that iron is an integral part of the chlorophyl molecule, a theory that long was held by scientists and still is a popular fallacy. The investigations of Hoppe-Seyler in 1879, which led to the erroneous hypothesis that chlorophyl is a lecithin, did, nevertheless, establish a definite structural relationship with hemin. Stokes[5] from optical data concluded that chlorophyl consists of two substances; and Borodin,[1] in alcohol mounts of sections of *Heracleum* leaf, secured beautiful triangular crystals, but their work was ignored until Willstätter showed its fundamental value.

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[1] Investigations on Chlorophyl, translated by Schertz and Merz, Lancaster, 1927, from the German edition, Berlin, 1913; includes plates showing absorption spectra and crystals of chlorophyls and carotenoids.

[2] Compt. rend. 1915, **160**, 739.

[3] Proc. Roy. Soc. Victoria 1918, **30**, 178.

[4] Compt. rend. 1851, **33**, 689.

[5] Proc. Roy. Soc. 1864, **13**, 144; J. Chem. Soc. 1864, **17**, 3[illegible]4.

The work of Tschirch,[2] Marchlewski,[3] and Hartley[4] established that iron is not a constituent of the molecule and that pyrrole derivatives are split off on decomposition, but they did not suggest the configuration of the molecule or even the presence of magnesium.

Investigations conducted in Willstätter's laboratory show:

First. Chlorophyl is not a single substance but consists of chlorophyl *a* and chlorophyl *b* to which he assigned the formulas $C_{55}H_{72}O_5N_4Mg$ and $C_{55}H_{70}O_6N_4Mg$ respectively.

Second. Both forms are esters, consisting of the alcohol *phytol*, $C_{20}H_{40}O$, in combination with a *nitrogenous complex* containing four pyrrole nuclei—the pentagons in the formula of Conant et al. given below—and one atom of *magnesium* with two whole and two " partial " valences.

Third. By alkaline hydrolysis, *chlorophyllins*, as well as phytol, are split off, and these by treatment with concentrated alcoholic alkali break up into *phyllins*, each containing one atom of magnesium to four of nitrogen. Phyllins with acid break up into poly- and mono-basic carboxylic acids, known as *porphyrins*, which are magnesium-free.

Fourth. By treatment with acid, chlorophyl *a* yields *phytochlorin e*, and chlorophyl *b* yields *phytorhodin g*, in both cases in addition to phytol.

Fischer, Moldenhauer, and Süs[5] propounded their theories on the constitution of chlorophyl *a* which later were modified by Fischer and Siebel.[6]

Experiments by Conant, Hyde, Moyer, and Dietz[7] brought out that chlorophyl *a* contains the grouping —CHOH—CO—O—. Further experiments by Conant, Dietz, Bailey, and Kamerling[8] led to detailed structural formulas for chlorin *f* and chlorophyl *a*. They also suggested a lactam formula. Conant and Dietz[9] adopted the formula given below as best representing chlorophyl a_1, the predominant form of chlorophyl *a*.

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[1] Bot. Ztg. 1882, **40**, 608.

[2] Untersuchung über das Chlorophyll, 1884; Ber. deut. bot. Ges. 1887, **5**, 128.

[3] Chemie des Chlorophylls, Hamburg, 1895; Chemie der Chlorophylle, Braunschweig, 1909.

[4] J. Chem. Soc. 1891, **59**, 106; 1904, **85**, 1607.

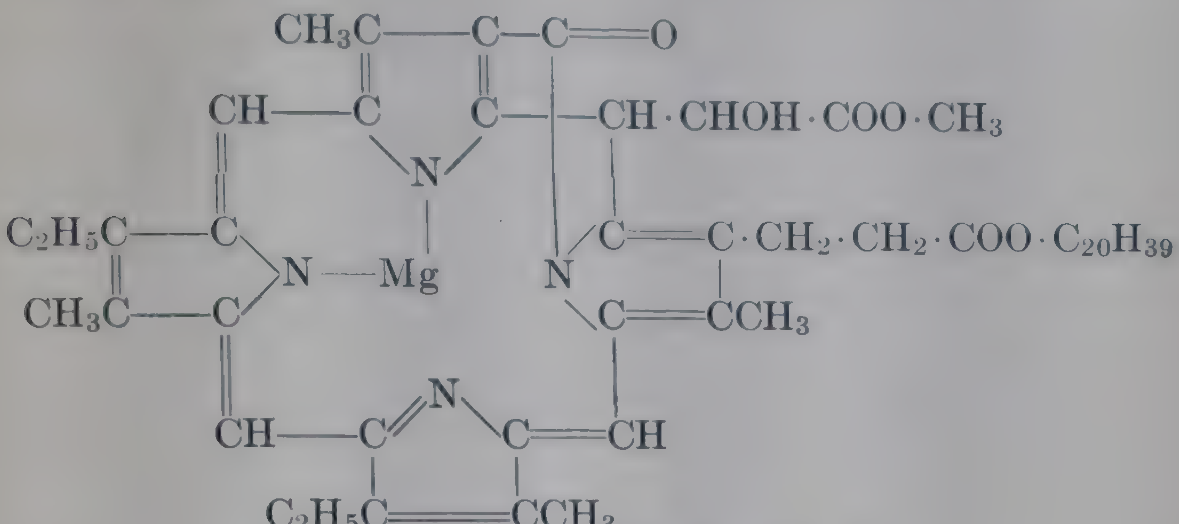
[5] Ann. 1931, **486**, 107.

[6] Ibid. 1932, **499**, 84.

[7] J. Am. Chem. Soc. 1931, **53**, 359.

[8] Ibid. 1931, **53**, 2382.

[9] Ibid. 1933, **55**, 839.

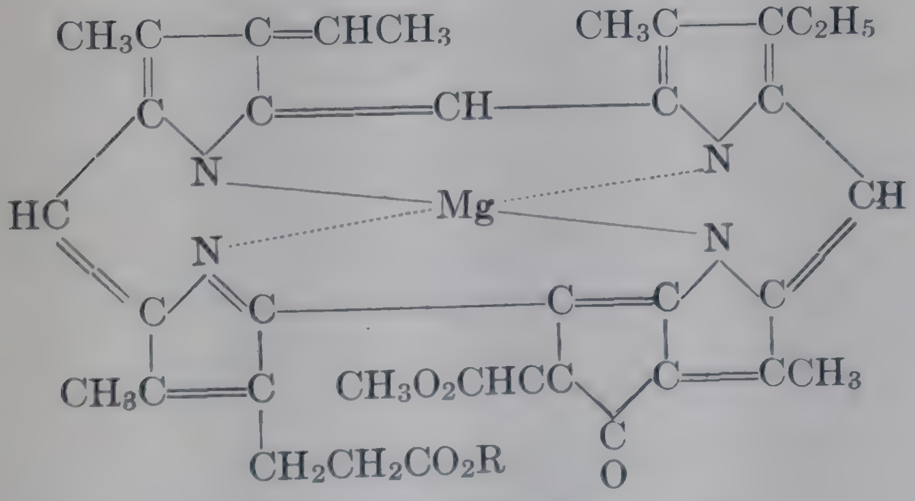


Chlorophyl a_1 (Conant and Dietz)

The above corresponds with the empirical formula $C_{55}H_{74}O_6N_4Mg$. Phytyl, $C_{20}H_{39}$, is the anhydride of the alcohol phytol, $C_{20}H_{39}OH$, which Willstätter and Stoll represent by the following structural formula: $CH_3(CHCH_3)_7 \cdot CCH_3 : CCH_3 \cdot CH_2OH$.

Conant and Dietz[1] state that there are probably two forms of chlorophyl *b* corresponding to the two forms of chlorophyl *a*. A formula suggested by Conant, Dietz, and Werner[2] has one of the CH groups, connecting adjoining pyrrole groups, replaced by CO.

The formulas of Stoll and Wiedemann[3] (with pyrrole rings expressed as rectangles) given on the next page and the formula of Fischer and Hasenkamp[4] which follows show other ideas of the grouping. R in all three formulas represents phytyl.



Chlorophyl *a* (Fisher and Hasenkamp)

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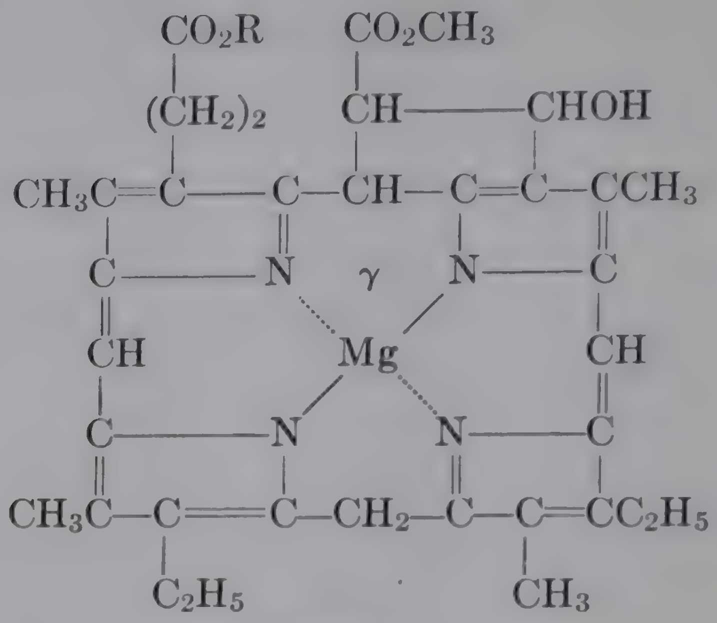
[1] Loc. cit.

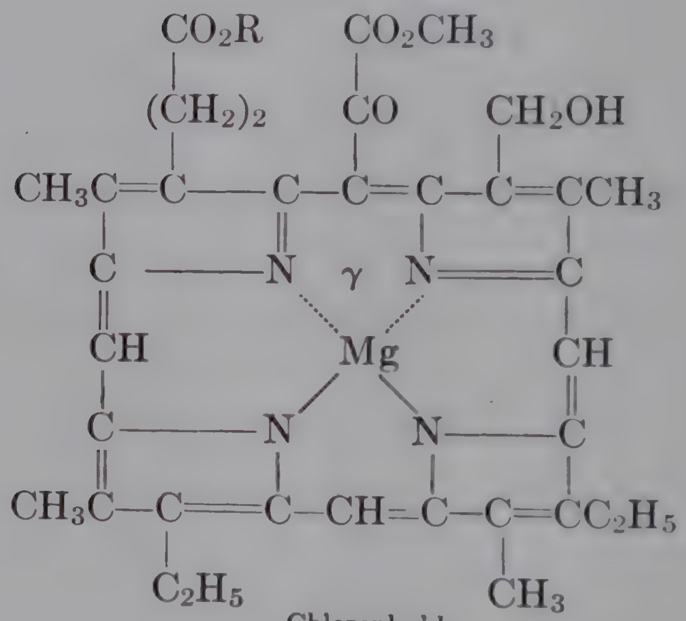
[2] J. Am. Chem. Soc. 1931, **53**, 4436.

[3] Helv. Chim. Acta 1932, **15**, 1128.

[4] Ann. 1934, **513**, 107:



Chlorophyl *a*



Chlorophyl *b*

(Stoll and Wiedemann)

In most points the formulas of the different authors agree, although this is obscured by dissimilar arrangement.

The general relationship between chlorophyl and hemoglobin has long been known. Recently Fischer and Riedl[1] have prepared for the first time the same porphyrin (mesoporphyrin) from both chlorophyl and hemin. Results on specific rotation at 25° C. by Stoll and Wiedemann[2] follow: chlorophyl *a* (+1H_2O) in acetone −262°; chlorophyl *b* (+1H_2O) in 90 : 10 methyl alcohol and acetone −267°.

Carotenoids.—This group includes hydrocarbon and oxygenated pigments.

Carotene, $C_{40}H_{56}$.—This orange-red pigment, or rather mixed pigment, was discovered, according to Brissemoret,[1] by Bouillon-LaGrange in 1815. The recent discovery that vitamin A (which see) is closely related makes it of special significance in nutrition. The empirical formula $C_{26}H_{38}$ of Arnaud has given place to $C_{40}H_{56}$ of Willstätter and Mieg,[2] who isolated the pigment from the stinging nettle and other plants and showed that it is identical with erythrophyl, chrysophyl, etiolene, and xantho-carotene. Willstätter and Stoll[3] give 0.017 per cent as the average amount in leaves, and Schertz[4] reports 0.015 per cent as present in carrots.

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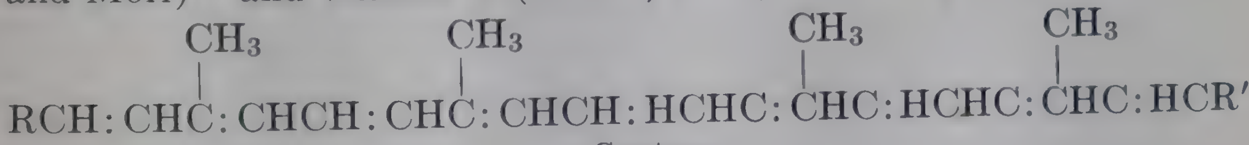
[1] Ann. 1931, **486**, 178.

[2] Helv. Chim. Acta 1933, **16**, 307.

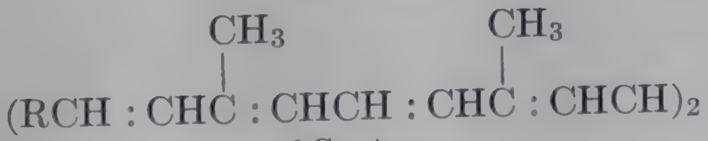
Results of studies by Zechmeister, Von Cholnoky, and Vrabély,[5] and by Zechmeister and Von Cholnoky,[6] confirmed by Pummerer and Rebmann,[7] suggest that the molecule is essentially aliphatic in structure, but the extensive work in Karrer's laboratory proves that a ring is present at each end of a chain. The increase in melting point on recrystallization of preparations of carotene, noted by Karrer, Helfenstein, Wehrli, Pieper, and Morf,[8] led to the isolation of two isomers, α- and β-carotene. Kuhn and Brockmann[9] from carotene as commonly prepared separated 0.1 per cent of γ-carotene with characteristic absorption bands and affinity for aluminum oxide. Winterstein[10] isolated a fourth form, δ-carotene, constituting 10 per cent of the total pigment present in the fruit peel of *Gonocaryum pyriforme*, 50 per cent being γ-carotene.

Following are recently proposed formulas for α-carotene (Karrer, Morf, and Walker),[11] β-carotene (Karrer, Helfenstein, Wehrli, Pieper, and Morf)[12] and vitamin A (Karrer, Morf, and Schöpp):[13]



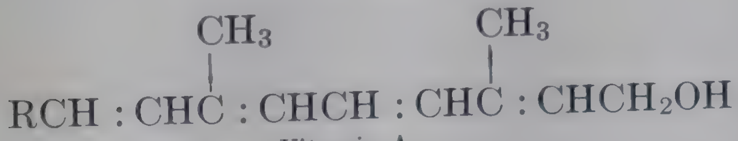
$$\mathrm{RCH\!:\!CH\overset{CH_3}{\overset{|}{C}}\!:\!CHCH\!:\!CH\overset{CH_3}{\overset{|}{C}}\!:\!CHCH\!:\!HCHC\!:\!\overset{CH_3}{\overset{|}{C}}HC\!:\!HCHC\!:\!\overset{CH_3}{\overset{|}{C}}HC\!:\!HCR'}$$

α-Carotene



$$\mathrm{(RCH : CH\overset{CH_3}{\overset{|}{C}} : CHCH : CH\overset{CH_3}{\overset{|}{C}} : CHCH)_2}$$

β-Carotene



$$\mathrm{RCH : CH\overset{CH_3}{\overset{|}{C}} : CHCH : CH\overset{CH_3}{\overset{|}{C}} : CHCH_2OH}$$

Vitamin A

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[1] Bul. sci. pharmacol. 1931, **38**, 483.

[2] Ann. 1907, **355**, 1.

[3] Loc. cit.

[4] J. Agr. Res. 1923, **26**, 283; 1925, **30**, 469.

[5] Ber. 1928, **61B**, 566.

[6] Ibid. p. 1534.

[7] Ibid. p. 1099.

[8] Helv. Chim. Acta 1931, **14**, 614.

[9] Naturwissensch. 1933, **21**, 44.

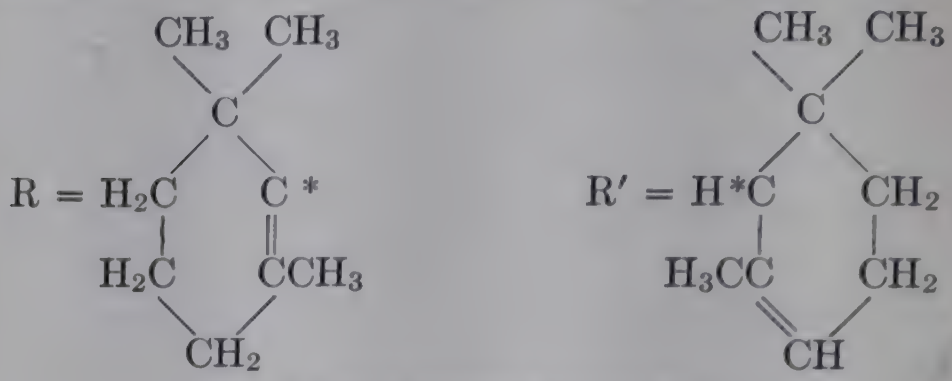
[10] Z. physiol. Chem. 1933, **219**, 249.

[11] Helv. Chim. Acta 1933, **16**, 975.

[12] Ibid. 1931, **14**, 614, 1033.

[13] Ibid. p. 1431.

In the above formulas R and R′ represent groups as follows:



Points of attachment are indicated by *

It will be noted that the formula for β-carotene is symmetrical, whereas that for α-carotene is unsymmetrical; furthermore, that the molecule of vitamin A differs from half the molecule of β-carotene in that H_2O is added. Theoretically β-carotene can yield twice as much vitamin A as α- or γ-carotene, which is in accord with the results of feeding experiments with rats by Kuhn, Brockmann, Scheunert, and Schieblich,[1] who also found that zeaxanthin, lutein, and violaxanthin are biologically inert.

Kuhn and Lederer[2] state that β-carotene (optically inactive) often is not accompanied by α-carotene (e.g., in spinach and peppers), but in no case has α-carotene been found to be the only carotenoid present. The total pigment of carrots consists of 10 to 20 per cent of the α form.

Karrer and Walker[3] separated α- and β-carotene by fractional absorption on calcium oxide or hydroxide from a petroleum ether solution and confirmed the formula $C_{40}H_{56}$. The α form showed melting point 187 to 188° C. (corrected) and specific rotation[4] at 18° C. + 315°. As purified by Karrer, Walker, Schöpp, and Morf[5] by calcium hydroxide adsorption, β-carotene shows immediately on spectroscopic examination a band at 620 μμ, α-carotene a band at 580 μμ; after a short time, owing probably to isomerization, a second band at 620 μμ appears in α-carotene.

Lycopene, $C_{40}H_{56}$.—Willstätter and Escher[6] showed that the pigments carotene and lycopene, both present in the tomato, have the same empirical formula. Lycopene is less soluble in carbon disulphide and takes up oxygen more readily than carotene; its solution is blue-red, whereas that of carotene is red-yellow; furthermore, its absorption spectrum is different. Lubimenko[1] considers that it is formed by the oxidation of chlorophyl. Lycopene, according to Karrer and Widmer[2] melts at 173° C. It is optically and physiologically inactive.

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[1] Z. physiol. Chem. 1933, **221**, 129.

[2] Ibid. 1931, **200**, 246.

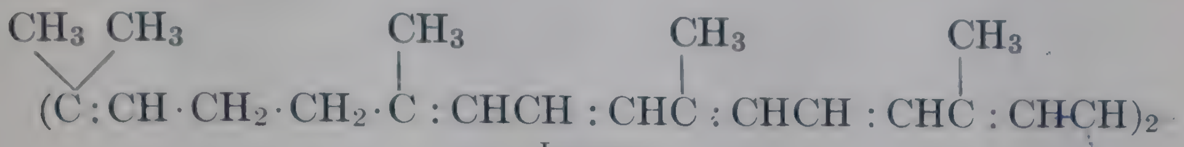
[3] Helv. Chim. Acta 1933, **16**, 641.

[4] The specific rotation of carotenoids is given for C light instead of the usual D (sodium line) light; thus in the present case $[\alpha]^{18}_{C}$, not $[\alpha]^{18}_{D}$, is + 315°.

[5] Nature 1933, **132**, 26.

[6] Z. physiol. Chem. 1910, **64**, 47.

The formula for lycopene, as substituted by Karrer, Helfenstein, Wehrli, and Wettstein[3] for one proposed by Karrer[4] and as confirmed by Karrer, Helfenstein, Pieper, and Wettstein[5] and by Kuhn and Grundmann,[6] follows:

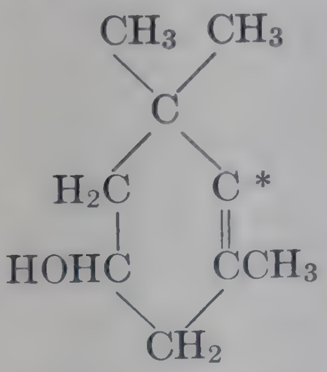


$$(\overset{CH_3\ CH_3}{C}:CH\cdot CH_2\cdot CH_2\cdot \overset{CH_3}{C}:CHCH:CH\overset{CH_3}{C}:CHCH:CH\overset{CH_3}{C}:CHCH)_2$$

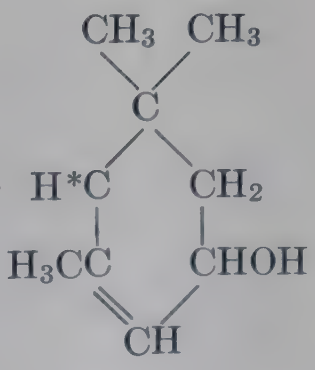
Lycopene

Xanthophyl, $C_{40}H_{56}O_2$.—Schertz[7] describes a modification of the method of Willstätter and Stoll[8] for the preparation of xanthophyl from cow pea leaves. Willstätter and Stoll[9] list the properties as follows: crystals, swallow-tail prisms; color by transmitted light, yellow; with petroleum ether and methyl alcohol, passes into lower layer; insoluble in petroleum ether (carotene is soluble); quite soluble in alcohol; rather difficultly soluble in carbon disulphide. Zechmeister and Tuzson[10] isolated from nettle leaves three xanthophyls, Karrer and Nilsson[11] only two, α and β. The latter authors state that both have a hydroxide group in each terminal ring, hence they are not, as was formerly assumed, oxides. Karrer, Helfenstein, Wehrli, Pieper, and Morf[12] conclude that leaf-xanthophyl, lutein, and zeaxanthin are isomers. The formulas for α- and β-xanthophyl, according to data secured by Karrer, Zubrys, and Morf,[13] are obtained by substituting, in the formulas for α- and β-carotene given above, the following values:

R =



R′ =



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[1] Rev. gén. botan. 1914, **25**, 475.

[2] Helv. Chim. Acta 1928, **11**, 751.

[3] Ibid. 1930, **13**, 1084.

[4] Z. angew. Chem. 1929, **32**, 918.

[5] Helv. Chim. Acta 1931, **14**, 435.

[6] Ber. 1932, **65B**, 1880.

[7] J. Agr. Res. 1925, **30**, 575.

[8] Loc. cit. p. 214.

[9] Loc. cit. p. 221.

[10] Ber. 1929, **62B**, 2226.

[11] Helv. Chim. Acta 1931, **14**, 843.

[12] Ibid. 1931, **14**, 6151.

[13] Ibid. 1933, **16**, 977.

Zeaxanthin, $C_{40}H_{56}O_2$.—Karrer, Saloman, and Wehrli[1] separated this pigment from yellow maize kernels by extraction with alcohol, solution in petroleum ether, removal of fat, and crystallization. Karrer, Wehrli, and Helfenstein[2] isolated it in the form of long, bright yellow crystals, melting at 201 to 202° C., free from the methyl group, slightly levorotatory in chloroform solution, and with spectroscopic absorption bands in alcoholic carbon disulphide solution at 480 to 495, and 445 to 461 $\mu\mu$.

Von Cholnoky[3] found zeaxanthin in paprika, and reports: melting point 206° C., specific rotation at 20° C. $-54°$, and spectrum absorption lines at 527 to 508, and 492.5 to 473 $\mu\mu$. See Garden Peppers.

Lutein, $C_{40}H_{56}O_2$.—Willstätter and Escher[4] prepared pure lutein from egg yolk, established its empirical formula, and noted that it differs from xanthophyl in its melting point (192 to 193° C.) and from carotene in its greater solubility in both ethyl and methyl alcohol. Karrer and Helfenstein[5] state that the specific rotation of egg lutein in chloroform is 71.7°.

Kuhn and Winterstein[6] showed that lutein is of common occurrence in the vegetable kingdom. From 1 kg. of dry powdered young grass they isolated 200 mg. of lutein, equivalent to that from 500 eggs. As a means of distinction from xanthophyl, they employ the formic acid color reaction. According to their theory, xanthophyl is destroyed in the body and lutein accumulates in the eggs. Kuhn and Smakula[7] calculate from the optical rotation and adsorption spectra data that the color of eggs consists of two parts of lutein to one of zeaxanthin. Von Cholnoky[3] isolated lutein from paprika as lustrous crystals, resembling those of carotene, melting at 192° C.

Capsanthin, $C_{36}H_{50}O_3$.—This substance occurs together with other carotenoids in the pericarp of species of red pepper, notably paprika and other varieties of *Capsicum annuum*. See Garden Peppers. Karrer, Helfenstein, Wehrli, Pieper, and Morf[8] believe that at least one end of the molecule is cyclic. Zechmeister and Von Cholnoky[9] at first suggested the formula $C_{34}H_{48}O_3$, but results of their later work are more in accord with the above formula or with $C_{35}H_{50}O_3$. Crystalline capsanthin, isolated from paprika by Von Cholnoky,[1] showed: melting point 174.5 to 176° C., specific rotation at 20° C. in chloroform −63 to −68°, and spectrum lines at 552, 554 to 532, 533, 513, and 514 to 493 $\mu\mu$.

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[1] Helv. Chim. Acta 1929, **12**, 741.

[2] Ibid. 1930, **13**, 268.

[3] Magyar Gyógyszerészrud. Társasag Értesitöje 1933, **9**, 400; Chem. Abs. 1934 **28**, 2031.

[4] Z. physiol. Chem. 1911, **76**, 214.

[5] Helv. Chim. Acta 1930, **13**, 86.

[6] Naturwissensch. 1930, **18**, 754.

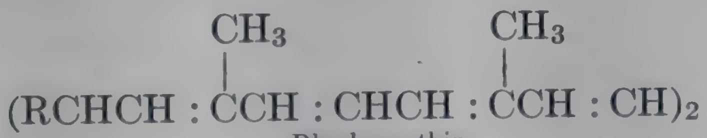
[7] Z. physiol. Chem. 1931, **197**, 161.

[8] Helv. Chim. Acta 1931, **14**, 614.

[9] Ann. 1927, **454**, 54; 1927, **455**, 70; 1928, **465**, 288; 1930, **478**, 95; 1931, **487**, 197.

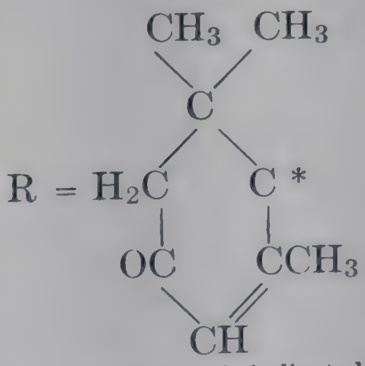
Physaliene, $C_{72}H_{116}O_4$.—Physaliene was shown by Kuhn and Brockmann[2] to occur together with carotene in the ripe red calyx of *Physalis franchetti*. In the green stage xanthophyl and carotene are the only carotenoids present. Kuhn and Wiegand[3] isolated the pigment from both *P. franchetti* and *alkekengi*. The spectrum bands in carbon disulphide centered at 5145, 4814, and 4498 A. U., and in petroleum ether at 4830, 4515, and 4230 A.U., the ratio of intensity being 8 : 10 : 1. Kuhn, Winterstein, and Kaufmann[4] derived the formula given above and report melting point 98.5 to 99.5° C. (corrected) and specific rotation in chloroform −30°. Zechmeister and Von Cholnoky[5] found in *Lycium halimifolium* 0.06 to 0.12 per cent of physaliene.

Rhodoxanthin, $C_{38}H_{50}O_2$.—Monteverde and Lyubimenko[6] note the occurrence of this pigment in autumn leaves and the shells of the seed of the yew (*Taxus baccata*) and state that it is an isomer of xanthophyl. Kuhn and Brockmann[7] assign to it the empirical formula given herewith, noting the absence of an alkoxy group, and state that it is the deepest in color of the group with an absorption band in benzene solution at 524 $\mu\mu$, 18 $\mu\mu$ beyond that of lycopene.



$$(\mathrm{RCHCH : \overset{\displaystyle CH_3}{\overset{|}{C}}CH : CHCH : \overset{\displaystyle CH_3}{\overset{|}{C}}CH : CH})_2$$

Rhodoxanthin



Point of attachment is indicated by *

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[1] Loc. cit.

[2] Z. physiol. Chem. 1932, **206**, 41.

[3] Helv. Chim. Acta 1929, **12**, 499.

[4] Ber. 1930, **63B**, 1489.

[5] Ann. 1930, **481**, 42.

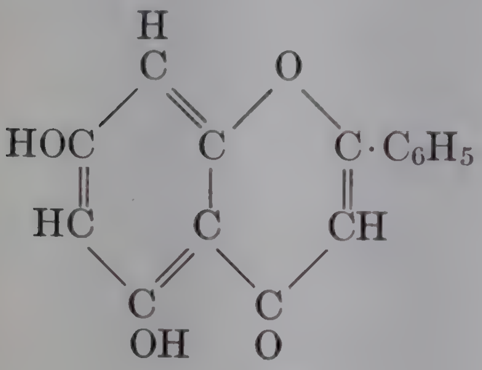
[6] Bul. Acad. Sci. St. Petersburg 1913, p. 1105.

[7] Ber. 1933, **66B**, 828.

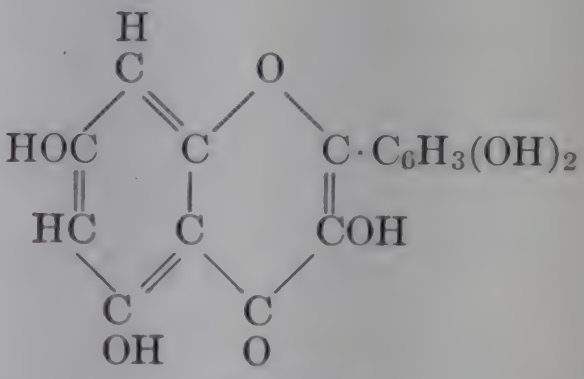
Violaxanthin, $C_{40}H_{56}O_4$, as isolated by Karrer and Morf[1] from *Viola tricolor*, had a melting point of 208° C. A ring structure, similar to that shown for R under xanthophyl, is believed to be present.

Fucoxanthin, $C_{40}H_{56}O_6$.—This carotenoid occurs in brown seaweeds. Karrer, Helfenstein, Wehrli, Pieper, and Morf[2] suggest that the molecule has two rings, both more highly hydroxylated than in xanthophyl.

Flavones and **Flavonols** are yellow colors which doubtless occur in many vegetables and fruits but have been studied mostly in barks and dyestuffs. Common examples are *chrysin* or dihydroxyflavone, $C_{15}H_{10}O_4$, and *quercetin* or tetrahydroxyflavonol, $C_{15}H_{10}O_7 + H_2O$. Unlike the related anthocyanins they do not exist in plants as oxonium compounds.



Chrysin



Quercetin

Lyochromes or **Flavins**. See Vitamin G.

Anthocyanins are glucosides related to the flavones in that they are phenopyrylium derivatives, but differ markedly in being oxonium salts with a quadrivalent oxygen in the molecule. Previous to the work in Willstätter's laboratory[3] here summarized, our knowledge was limited chiefly to color reactions such as the red or scarlet formed with acids, the blue or violet with sodium carbonate, and the red, purple, or blue precipitate with lead subacetate solution.

The molecule of the anthocyanins consists of one equivalent of an *anthocyanidin* (the chromogenic constituent) or its mono- or dimethyl derivative and one or two equivalents of a hexose (*dextrose* or *galactose*) or the pentose *rhamnose*. The color was extracted by acetic acid or other suitable solvent from a large amount of the vegetable material and converted in most cases into crystalline picrate from which in turn the hydrochloride was prepared. Decomposition into the chloride of the anthocyanidin and the sugar or sugars was effected by boiling with 20 per cent hydrochloric acid.

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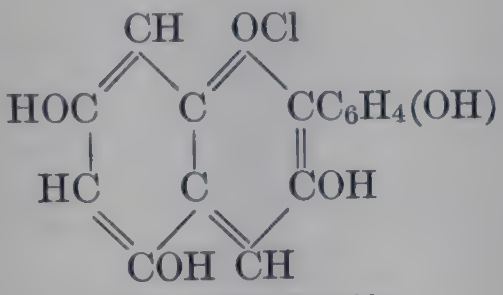
[1] Helv. Chim. Acta 1931, **14**, 1044.

[2] Ibid. p. 614.

[3] Ann. 1913, **401**, 189; 1915, **408**, 1; 1916, **412**, 113, 136, 149, 164, 178, 195, 217, 231; Sitzb. preuss. Akad. Wiss. 1914, p. 402; Ber. pharm. Ges. 1915, **25**, 438.

Three primary anthocyanidins, named after the flowers from whose anthocyanins they were first prepared, have been definitely identified. Their chlorides are as follows: (1) pelargonidin chloride, $C_{15}H_{11}O_5Cl$, (red geranium), (2) cyanidin chloride, $C_{15}H_{11}O_6Cl$, (corn flower), and (3) delphinidin chloride, $C_{15}H_{11}O_7Cl$, (larkspur). Anthocyanins may be separated from anthocyanidins by shaking in an acid solution with amyl alcohol in which only the latter are soluble. The anthocyanidins are split up by hot alkali into phloroglucinol and a phenolcarboxylic acid, pelagonidin yielding *p*-oxybenzoic acid, $C_6H_4(OH)COOH$, cyanidin yielding protocatechuic acid, $C_6H_3(OH)_2COOH$, and delphinidin yielding gallic acid, $C_6H_2(OH)_3COOH$. Below is given the structural formula of pelargonidin chloride from which the formulas of cyanidin and delphinidin chlorides differ in that the group $C_6H_4(OH)$ is replaced respectively by $C_6H_3(OH)_2$ and $C_6H_2(OH)_3$. Being oxonium salts, the O attached to the Cl has four bonds.



Pelargonidin Chloride

The following data were secured in Willstätter's laboratory:

Fruit	Name of anthocyanin	Formula of anthocyanin chloride	Component anthocyanidin	Component sugars
Cherry..........	keracyanin	$C_{27}H_{31}O_{15}Cl$	cyanidin	1 dextrose, 1 rhamnose
Sloe............	"	"	"	" "
Plum...........	prunicyanin	"	"	" "
Raspberry.......	....	....	"	....
Foxberry........	idæin	$C_{21}H_{21}O_{11}Cl$	"	1 galactose
Grape...........	enin	$C_{23}H_{25}O_{12}Cl$	enedin *	1 dextrose
Whortleberry....	myrtillin	$C_{22}H_{23}O_{12}Cl$	myrtillidin †	1 galactose

* Dimethyl delphinidin. † Monomethyl delphinidin.

In the fruit of several species of American grapes, Anderson[1] found an anthocyanin the anthocyanidin of which is monomethyl delphinidin. The formation of anthocyanins in fruit picked green is attributed by

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[1] J. Biol. Chem. 1923, **57**, 795; 1924, **61**, 97.

Politis[1] to the dying of the epidermal cells, thus favoring the reduction of flavones. While on the tree, when oxidation processes prevail, the formation of anthocyanins is retarded because oxyflavones are reduced to anthocyanidins.

Leuco-anthocyanins are stated by Robinson and Robinson[2] to be colorless progenitors of anthocyanidin occurring in a great variety of vegetable growths.

Odorous Constituents.—Vegetables with marked amounts of odorous constituents include the bulbs and leaves of members of the onion family containing *allyl sulphide* and the leaves and petioles of the parsley family containing volatile oils rich in terpenes and derivatives.

Examples of fruits the odor of which corresponds with a single substance are the banana, containing *amyl acetate,* and the American grape, containing *methyl anthranilate.* Other fruits, so far as studied, contain mixtures of ethers, alcohols, aldehydes, and volatile oils. Various *amyl esters* occur in the apple and *linalool esters* in the peach; both fruits contain also *acetaldehyde* and minor odorous constituents. Among the odorous constituents of the orange are *acetone* and *acetaldehyde.* In squeezing the juice from the orange and lemon a certain amount of *volatile oil* may be introduced from the peel. The resinous odor of the mango is due to volatile oil.

Enzymes occur in great variety in fruits and play important roles in ripening.

Mineral Constituents.—Fruits and vegetables, excepting seeds, yield an alkaline ash due to the preponderance of basic over acid-forming elements. The free organic acids burn to carbon dioxide and their salts to carbonates.

Minor Mineral Constituents.—It may be assumed, unless otherwise stated, that the figures given under each product were obtained on the edible portion and that contamination, such as adhering dirt or spray residue, had been removed by washing, paring, or otherwise. The excessively high amounts of arsenic and lead reported by White[3] and Myers et al.[4] show the extent of contamination due to faulty method of spraying and failure to wash the fruit. The most instructive figures are those obtained on products known to have been grown without spraying.

Some of the authors quoted failed to state the part analyzed or the exact meaning of the term "edible portion."

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[1] Praktika (Akad. Athenon) 1928, **3**, 440.

[2] Biochem. J. 1933, **27**, 206.

[3] Ind. Eng. Chem. 1933, **25**, 621.

[4] Ibid. p. 624.

Numerous results on iron and tin in representative fruits and vegetables, packed in cans coated with different weights of tin and stored from one month to over a year, are given in the report issued by the National Canners Association.[1] Since the publication of that report marked advance has been made in preventing contamination.

Vitamins.—At the time Volume I was written the subject of vitamins was in the transition from empiricism based on animal experimentation to organic chemistry. More recently substantial progress has been made in determining the chemical nature of these substances, and it is now, in certain cases, possible to express more or less accurately in terms of definite compounds certain physiological properties hitherto designated merely as capital letters. Although the time has not come when McCollum's alphabetical nomenclature based on animal tests or even on color reactions, can be entirely displaced by chemical terms, since several substances, perhaps of different chemical groups, may have similar physiological action or may react in the same manner, it is, however, within the province of this work to describe the substances which have been identified and note the cases where their isolation in food products has been accomplished.

At present six vitamin groups are fairly well defined. Of these A, D, and E are soluble in fat, and B, C, and G are soluble in water. Considering only natural foods, vitamin D is limited to the animal kingdom but is present in cereal products and certain other vegetable foods after irradiation. On the other hand, vitamin C is limited to vegetable foods and liver. The others are present in both animal and vegetable foods but not always the same foods. The brief descriptions of the different vitamins which follow are limited to their occurrence, constitution, and properties. Their physiological action is treated in the monograph of Sherman and Smith[2] and briefly in the chart of Weston and Levine.[3]

Vitamin A, $C_{20}H_{30}O$.—The chief, if not the only, chemical substance of biological vitamin A, a protective against infection and ophthalmia, is a fat-soluble substance related to carotene. It occurs more or less abundantly in the common green, yellow, and orange vegetables and fruits, as well as in milk (butter fat), eggs, liver (liver oils), and other organs. The observations of Steenbock,[4] Rosenheim and Drummond,[1] and Steenbock and co-workers[2] that vitamin A potency is often, but not always, associated with a yellow pigment was prophetic of Karrer's achievements in isolating a definite carotenoid-like substance with properties of biological vitamin A and in framing structural formulas for this substance as well as related carotenoids (see Carotene above).

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[1] Relative Value of Different Weights of Tin Coating on Canned Food Containers, Washington, 1917.

[2] The Vitamins: Am. Chem. Soc. Monograph No. 6, New York, 1931.

[3] Published by South Carolina Food Research Commission, Charleston, S. C., price ten cents.

[4] Sci. 1919, **50**, 342.

As separated by Karrer, Morf, and Schöpp[3] from the unsaponifiable matter of mackerel oil by adsorption on fuller's earth from a petroleum ether solution, vitamin A is a faintly yellow, optically inactive alcohol which flows only when heated. It forms esters with *p*-nitrobenzoic acid and acetic acid. In their study of isomers, Karrer, Schöpp, and Morf[4] found that carotenoids not affecting growth have no unsubstituted β-ionone ring system, hence they conclude that this structure is essential for producing growth. It is significant that lutein, zeaxanthin, and lycopene are biologically inert and as shown by Brockmann and Tecklenburg[5] do not form vitamin A in rat liver. From β-carotene the theoretical yield should be 20 per cent, but actually only 8 per cent was found in the liver; α- and γ-carotene should yield half as much as β-carotene, but actually the yield was less than half. Kuhn and Brockmann[6] previously had found the α and β forms equally effective. In small doses Moore[7] found that carotene is as efficient as vitamin A.

Vitamin A, in the chemical sense, is a collective term, since by adsorption with calcium oxide or hydroxide Karrer, Walker, Schöpp, and Morf[8] separated it into α- and β- forms, following the method employed in the case of α- and β- carotene. The main fraction, consisting of the β-form, showed a spectroscopic band at 328 μμ; the other fraction showed one at 270 μμ. Previously Karrer and Schöpp[9] separated vitamin A from carotene in a petroleum ether solution containing 10 per cent of methyl alcohol by its adsorption on fibrous aluminum oxide and from xanthophyl, zeaxanthin, violaxanthin, capsanthin, and fucoxanthin by adsorption of these on calcium carbonate.

The oxide of β-carotene is stated by Karrer, V. Euler, Hellström, and Klussmann[10] to have the same influence on growth as the unoxidized form. Other derivatives of carotenoids will doubtless have nutritional significance.

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[1] Lancet 1920, I, p. 862.

[2] J. Biol. Chem. 1920, **41**, 81; 1921, **47**, 89, 303; 1922, **51**, 63.

[3] Helv. Chim. Acta 1931, **14**, 1431.

[4] Ibid. 1932, **15**, 1158.

[5] Z. physiol. Chem. 1933, **221**, 117.

[6] Ber. 1931, **64B**, 1859.

[7] Biochem. J. 1933, **27**, 898.

[8] Nature 1933, **132**, 26.

[9] Helv. Chim. Acta 1932, **15**, 745.

[10] Arkiv. Kemi, Min. Geol. 1932, **11B**, No. 3.

Color Tests.—Of particular importance are the color tests based on the observation of Hager[1] that cod-liver oil in a fat solvent gives a blue color with sulphuric acid, which, as shown by Drummond and Watson,[2] varies in intensity with the vitamin potency. Carr and Price[3] substitute antimony trichloride for the sulphuric acid. Gillam, Heilbron, Morton, and Drummond[4] employ antimony trichloride in preparing what appears to be the biologically inert isocarotene of Kuhn.

Vitamin B, $C_{12}H_{16}N_4OS$.—As first prepared, vitamin B was a mixture of vitamins, one of which, B_2, is now known as vitamin G. As now restricted, vitamin B occurs in cereal germs and bran, nuts, a great variety of fruits and vegetables, milk, cheese, eggs, and animal organs. Funk[5] first called attention to the antineuritic and antiberiberi water-soluble vitamin present in the arginine fraction from the hexone bases obtained from an acid alcoholic extract of rice polishings. Williams[6] carried out extensive studies before the elimination of vitamin G was effected.

Windaus, Tschesche, Ruhkopf, Laquer, and Schultz,[7] who analyzed the picrolonate of supposedly pure vitamin B, suggest the formula $C_{12}H_{17}N_3OS$; Windaus, Tschesche, and Ruhkopf,[8] who analyzed several salts, give $C_{12}H_{16}N_4OS$. Seidell and Smith[9] obtained from a specially prepared vitamin B concentrate, by treatment with alcoholic picrolonic acid, a substance of special purity crystalling in rods, or prisms having high antipolyneuritic action. Jansen, Wibaut, Hubers, and Wiardi[10] also analyzed preparations of the vitamin. Windaus, Tschesche, and Grewe,[11] by oxidation of the vitamin, obtained two products, but did not ascertain their structure.

Williams and co-workers[12] demonstrated that two nucleii are present, one pyrimidine, the other thiazole, and regard the following formula for the chloride-hydrochloride of the vitamin as the most probable:

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[1] Pharm. Zentralh. 1885, **26**, 13.

[2] Analyst 1922, **47**, 341.

[3] Biochem. J. 1926, **20**, 497.

[4] Ibid. 1932, **26**, 1174.

[5] J. Physiol. 1911, **43**, 395.

[6] J. Biol. Chem. 1916, **25**, 437; with Seidell 1916, **26**, 431; 1917, **29**, 495; J. Ind. Eng. Chem. 1921, **13**, 1107.

[7] Z. physiol. Chem. 1932, **204**, 123.

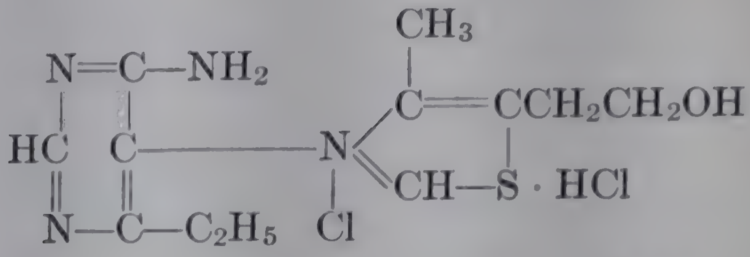
[8] Nachr. Ges. Wiss. Göttingen Math.-physik. Klasse 1932, p. 342.

[9] J. Am. Chem. Soc. 1933, **55**, 3380.

[10] Rec. trav. chim. 1933, **52**, 366.

[11] Z. physiol. Chem. 1934, **228**, 27.

[12] J. Am. Chem. Soc. 1935, **57**, 229, 517, 536.



√ *Vitamin C.—Ascorbic* or *ascorbinic acid*, $C_6H_8O_6$, a hexuronic acid, isomeric with glucuronic acid, isolated by Szent-Györgyi[1] from the cortex of adrenal glands, also from cabbages and oranges, was later isolated by King and Waugh[2] from an antiscorbutic concentrate of lemon juice. During the same year Svirbely and Szent-Györgyi,[3] Hirst and Reynolds,[4] and Haworth[5] studied its physiological action. Ascorbic acid also has been isolated from paprika by Svirbely and Szent-Györgyi,[6] and from red peppers of other types by Bachstez.[7] It doubtless is of wide distribution and accounts in large part, if not entirely, for the vitamin C potency of fruits, vegetables, and liver.

The irregular aggregates of rectangular crystals, obtained by Hirst and Reynolds[4] from the crude substance isolated from the cortex of adrenal glands, showed specific rotation at 20° C. in aqueous solutions (sodium light) immediately 23°, in three days 31°, and in eleven days 0°. The *d*- and *l*-ascorbic acids synthesized by Reichstein, Grüssner, and Oppenauer[8] had the following properties respectively: melting point 187 to 189° and 186 to 189° C.; specific rotation at 23° C. −48° and +48°; alkali equivalent 176.2 and 175.5; iodine equivalent 87.4 and 87.1. Synthetic *l*-ascorbic acid is identical with the natural acid.

Szent-Györgyi[9] discovered an enzyme, *hexoxidase*, which appears to act in plant respiration as a carrier of oxygen to ascorbic acid in forming a reversible oxidation product.

Hirst and Zilva[10] state that ascorbic acids obtained from different sources are not alike in their antiscorbutic action and point out the limitations of biological analytical methods. The acid they obtained by reduction of the oxidized substance was found to be as active as the original substance. As examined by Dalmer and Moll,[1] an acid isolated by Maurer and Schiedt,[2] has the same empirical formula as ascorbic acid but is orally only one-fortieth as active.

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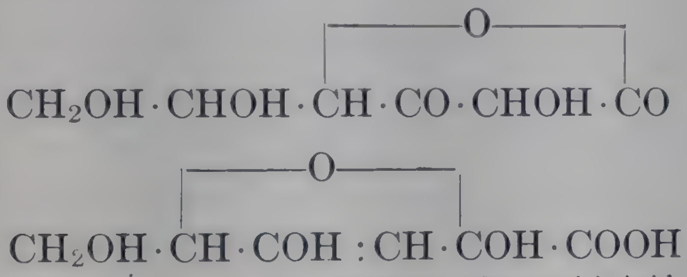
[1] Biochem. Z. 1927, **181**, 433; Nature 1927, **119**, 782; Biochem. J. 1928, **22**, 1387.
[2] Science 1932, **75**, 357.
[3] Nature 1932, **129**, 576.
[4] Ibid. 1932, **129**, 576.
[5] Ibid. 1932, **129**, 576.
[6] Biochem. J. 1933, **27**, 279.
[7] Giorn. chim. ind. appl. 1933, **15**, 510.
[8] Nature 1933, **132**, 280; Helv. Chim. Acta 1933, **16**, 561, 1019.
[9] J. Biol. Chem. 1931, **90**, 385.
[10] Biochem. J. 1933, **27**, 1271.

Haworth[3] suggested that hexuronic acid is the 6-carboxylic acid of a ketohexose, with no apparent relationship to levulose or the ketose corresponding to *d*-galactose. Cox, Hirst, and Reynolds[4] proposed a constitutional formula which, although lacking a bridge, was considered by Haworth[5] to be nearer the truth than the hydrofuran formulas given in the earlier of two papers each by Micheel and Kraft[6] and by Reichstein, Grüssner, and Oppenauer,[7] although in both the later papers a new formula advanced by Haworth in essential details is approved. Several formulas have emanated from Karrer's laboratory. The more likely of two proposed by Karrer, Schwarzenbach, and Schöpp[8] and Haworth's formula are given below.



$CH_2OH\cdot CHOH\cdot CH\cdot CO\cdot CHOH\cdot CO$ (Haworth)

$CH_2OH\cdot CH\cdot COH : CH\cdot COH\cdot COOH$ (Karrer et al.)

Ascorbic (Hexuronic) Acid

Vitamin D.—This antirachitic, fat-soluble vitamin differs from the others now known in that it occurs naturally only in certain animal foods, notably milk (butter fat), eggs, fish liver (oil), and shell fish, but is formed by irradiating cereals and certain other vegetable products. Several authors have called attention to its presence in ergosterol, or cholesterol containing ergosterol, irradiated with ultraviolet rays, hence the name viosterol. Waddell[9] believes that irradiated cholesterol is more active than irradiated ergosterol, thus explaining anomalous results based on the assumption that ergosterol is the basic provitamin D. Remesov[10] considers vitamin D to be a keto tautomeric form of cholesterol produced by ultraviolet rays from the inactive enol form, furthermore that it has the action of an oxidizing enzyme. Karrer and Von Euler[1] suggest that vitamin D is a purine derivative.

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[1] Z. physiol. Chem. 1933, **222**, 116.

[2] Ber. 1933, **66B**, 1954.

[3] Nature 1932, **129**, 576.

[4] Ibid. 1932, **130**, 888.

[5] Chem. & Ind. 1933, p. 482.

[6] Z. physiol. Chem. 1933, **215**, 215; 1933, **222**, 235.

[7] Helv. Chim. Acta 1933, **16**, 561, 1019.

[8] Ibid. 1933, **16**, 302.

[9] J. Biol. Chem. 1934, **105**, 711.

[10] Biochem. Z. 1932, **250**, 560.

Askew and co-workers[2] obtained, by the double distillation of irradiated ergosterol in a high vacuum and crystallization from dilute alcohol, crystals of *calciferol*, a substance containing an alcohol group, melting at 123 to 125° C. and rotating $[\alpha]^{20}_{5681} + 260°$. Other isomers with widely different properties were also obtained. They state that pure calciferol is not identical with vitamin D_1 but resembles vitamin D_2. Bernal[3] has studied calciferol and four other isomers of similar properties.

Vitamin E.—Little is known of the chemical nature of this fat-soluble, antisterility vitamin occurring in cereal grains (notably the germ), leguminous seeds, various oil seeds, milk, meat, and egg yolk.

Vitamin G (*Lyochromes* or *Flavins*).—At first vitamin B was described as having antipellagric, as well as antineuritic, action. Later two separate individuals B_1 and B_2 were recognized, and still later the name of B_2 was changed to G. Although the status of vitamin G is somewhat uncertain, it appears to be present in a wide variety of foods, including numerous vegetables and fruits, cereal germs, meat, animal organs, fish, eggs, and milk, hence there is little danger of deficiency when the diet is reasonably diversified.

Chemically the vitamin appears to be a pigment or group of pigpigments. Ellinger and Koschara[4] proposed the name *lyochromes* for a group of crystalline pigments with yellow-green fluorescence which they obtained as (1) spheroidal aggregates, (2) hexagonal, nearly rhombohedral plates, and (3) red-brown stellate aggregates of lance-shaped leaflets, containing 21.6, 31.9, and 31.3 per cent of nitrogen respectively, also (4) (lactoflavin) forming fine yellow needles or red rods decomposing at 270 to 273° C. Analysis of the last corresponds with the formula $C_{16}H_{20}O_6N_4$ or $C_{11}H_{20}O_7N_4$.

Kuhn, György, and Wagner-Jauregg,[5] who published their preliminary paper on the same date as the foregoing authors, isolated from various foods nitrogenous substances of the lyochrome group with high antipellagric potency which they called flavins with or without the prefix showing the source (ovoflavin, lactoflavin, etc.). Wagner-Jauregg and Ruska[1] observed that the pure flavins are decolorized by yeast, minced muscle or organs, especially in the presence of certain lactates, succinates, citrates, aldehydes, etc., but the color reappears on shaking with air, that is, they act similarly to methylene blue as oxygen carriers. The fluorescence of lyochromes is stated by Kuhn and Moruzzi[2] to be due only to the ampholyte, hence it is destroyed by strong acid or alkali.

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[1] Arkiv. Kemi, Min. Geol. 1933, **11B**, No. 16.

[2] Proc. Roy. Soc. (London) 1930, **107B**, 76; 1931, **108B**, 340; Nature 1931, **128**, 758.

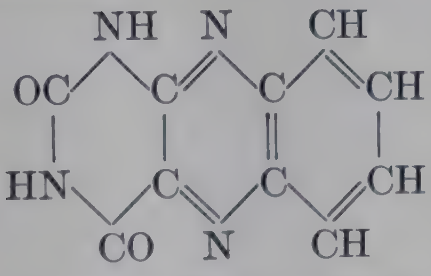
[3] Nature 1932, **129**, 277.

[4] Ber. 1933, **66B**, 315, 808, 1411.

[5] Ibid. p. 317.

As shown by Kuhn and Rudy,[3] lactoflavin is optically inactive in neutral and acid solutions, but is levorotatory in solutions of sodium hydroxide, the maximum specific rotation being, at 0.1 normal, 20° C. D light $-115°$ and Cd light $-60°$. They[4] demonstrated that flavins in the sunlight are converted into *lumiflavins* which have a blue fluorescence.

Kuhn, Rudy, and Wagner–Jauregg[5] established the identity of flavin with vitamin G (B_2) and showed that the lactoflavin molecule consists chiefly of *alloxazine*, $C_{10}H_6N_4O_2$, in combination with the sugar-like side chain—$CH(OH)\cdot CH(OH)\cdot CH(OH)\cdot CH_2(OH)$. Their analysis conforms closely to the formula $C_{17}H_{20}N_4O_6$ and to that of trimethyl-alloxazine with the side chain attached. Karrer and Schöpp[6] believe that the skeleton of lactoflavin and ovoflavin, both of which pass into lumiflavin by irradiation, is 6,7-*dimethyl-alloxazine*, although they are uncertain whether the side chain is the same in both. The configuration of alloxazine is as follows:



Alloxazine (Kuhn and Bär)[7]

Three dimethyl-alloxazines were synthesized by Stern, Holiday, and Stern;[8] trimethyl-flavin with properties of lumilactoflavin was synthesized by Kuhn and Reinemund.[9] Various other alloxazines and isoalloxazines have been synthesized by Karrer,[10] assisted by Salomon,

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[1] Ber. 1933, **66B**, 1298.

[2] Ibid. 1934, **67B**, 888.

[3] Ibid. 1935, **68B**, 169.

[4] Ibid. 1934, **67B**, 892, 1125, 1298, 1826, 1936.

[5] Ibid. 1933, **66B**, 1950.

[6] Helv. Chim. Acta 1934, **17**, 1557.

[7] Ber. 1934, **67B**, 898.

[8] Ibid. p. 1442.

[9] Ibid. p. 1932.

[10] Helv. Chim. Acta 1934, **17**, 1010, 1165, 1516; 1935, **18**, 69, 426; Ber. 1935, **68B**, 216.

Schlittler, Schöpp, Pfaehler, Benz, and Fritzsche. According to Kuhn and Weygand,[1] synthetic 10-tetra-acetoxy-amyl-7,8-dimethyl-iso-alloxazine (arabinose configuration) acts physiologically similar to vitamin G; these authors[2] in later experiments prepared tetraacetyl-6,7-dimethyl-9-*l*-arabinoflavin conforming to natural (tetraacetyl) lactoflavin in properties.

That vegetable and animal lyochromes are identical, according to Karrer and Schöpp[3] is indicated by the agreement in melting point and crystal formation of a preparation from dandelion flowers with preparations from liver, milk, egg white, and egg yolk. The amount of lactoflavin in plants as determined by Kuhn, Wagner-Jauregg and Kaltschmitt,[4] always exceeds that of lumiflavin; from 103 kilograms of alfalfa hay they isolated 30 milligrams. In liver the amount is fairly constant regardless of the food, which is not true of vitamin A and ascorbic acid. A comparison by V. Euler, Adler, and Schlötzer[5] of the amounts of flavin in foods found by a fluorometric method agreed with values by biological tests. According to V. Euler and Adler,[6] 70 to 100 per cent of the flavin of liver, kidney, and eggs, but only 20 to 25 per cent of the flavin of milk is combined.

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[1] Ber. 1934, **67B**, 2084.

[2] Ibid. 1935, **68B**, 166.

[3] Helv. Chim. Acta 1934, **17**, 771.

[4] Ber. 1934, **67B**, 1452; 1935, **68B**, 128; Z. physiol. Chem. 1935, **232**, 36.

[5] Z. physiol. Chem. 1934, **226**, 87.

[6] Arkiv. Kemi, Mineral. Geol. 1934, **11B**, No. 28.

PART I

VEGETABLES

PART I

VEGETABLES[1]

A concise definition of vegetables is not possible. Certain fruits in the botanical sense, such as melons and tomatoes, are on the border line between fruits and vegetables, and certain others, such as pumpkins, garden peppers, string beans, and okra, are classed as vegetables because of lack of fruity flavor and for other obvious reasons. Most leguminous seeds, whether fresh or dry, belong in the vegetable class, as do also most succulent seeds, leaves, stems, roots, and subterranean stems (tubers, corms, rhizomes) used either raw or cooked for food.

Structure is considered in the introduction to Volume I.

Protein is abundant in leguminous seeds and leaf vegetables but not in roots and subterranean stems. In sprouting seeds and green shoots amino acids, such as glutamine (glutamic acid) and asparagine (aminosuccinic acid), are present. Betaine and choline are among the representatives of the nitrogenous bases.

Fat, although the chief non-nitrogenous reserve material of some leguminous seeds, is a minor constituent of other classes of vegetables. As determined by ether extraction in leaves and other green parts it is contaminated with chlorophyl.

Starch or cell wall carbohydrates replace fat as reserve material in seeds of certain species, the leguminous seeds furnishing examples of the three types. The carbohydrate reserve of roots and subterranean stems may be chiefly starch (e.g., carrot, potato), sugar (e.g., beet, sweet potato), inulin (e.g., salsify), or one or more ill-defined substances little understood (e.g., turnip). All vegetables, whether or not starchy, contain more or less sugar, the proportion of sucrose to reducing sugar being variable.

Although vegetables as handled in the kitchen do not show jellying properties, sugar beets (especially the pomace), turnips, and other roots are rich sources of pectin. Special studies have been made of the pectin of the tomato. See Introduction.

Acid vegetables are unusual, the tomato and rhubarb being noteworthy exceptions. The vegetables richest in nutrients usually have a bland or sweetish taste. The pungency of the onion group is due to allyl sulphide, of the mustard family to sinigrin (mustard oil), and of the parsley family to terpenes and derivatives.

---

[1] Includes dry legumes.

Chlorophyl occurs in leaf vegetables, except when blanched, and others of a green color. Of the other pigments, carotenoids predominate, anthocyanins occurring only in a few vegetables such as the beet and radish.

The ash of vegetables, other than seeds, since there is a preponderance of bases over acid-forming mineral elements in the fresh material, contains carbonates and is consequently alkaline.

MUSHROOMS

Edible fleshy fungi are commonly known as mushrooms, although strictly speaking the term includes both poisonous and non-poisonous species. Numerous species are gathered by peasants and connoisseurs in field and woods, and members of the genus *Agaricus*, especially the species *A. campestris*, are cultivated commercially both in Europe and America.

Although it is not the province of this work to furnish schemes for the distinction of poisonous from non-poisonous forms, the following rules by Farlow[1] are generally accepted as of value for beginners:

(1) Avoid fungi when in the button or unexpanded stage; also those in which the flesh has begun to decay, even if only slightly.

(2) Avoid all fungi which have stalks with a swollen base surrounded by a sac-like or scaly envelope, especially if the gills are white.

(3) Avoid fungi having a milky juice, unless the milk is reddish.

(4) Avoid fungi in which the cap, or pileus, is thin in proportion to the gills, and in which the gills are nearly all of equal length, especially if the pileus is bright colored.

(5) Avoid all tube-bearing fungi in which the flesh changes color when cut or broken or where the mouths of the tubes are reddish, and in the case of other tube-bearing fungi experiment with caution.

(6) Fungi which have a sort of spider web or flocculent ring around the upper part of the stalk should in general be avoided.

Rules 1, 2, and 5 may for the beginner be regarded as absolute, with the exception to rule 2, *Amanita cæsarea* . . . , the gills of which are yellow. Rules 3, 4, and 6 have more numerous exceptions, but these rules should be followed in all cases unless the collector is content to experiment first with very small quantities and learn the practical result.

STRUCTURE.—Mushrooms are parasitic or saprophytic and contain no chlorophyl. The innumerable septate threads (*hyphæ*), which run through the soil or host, come to the surface (with very few exceptions, as for example truffles) forming the fleshy bodies, known in common parlance as mushrooms, which differ greatly in form and color with the species but in all cases function as the bearers of the spores. The mass of hyphæ is known collectively as *mycelium*. The food value is largely in these threads, for, although the minute spores are borne in enormous numbers, they form a comparatively small portion of the bulk of the edible part.

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[1] Yearbook U. S. Dept. Agr. 1897, p. 470.

Although the gross appearance suffices in collecting mushrooms for the table, microscopic examination is indispensable in studying their reproduction, in settling certain points in classification, and in the diagnosis of finely divided material.

CLASSIFICATION.—The species most commonly gathered or found on the market are best understood by the following classification:

- I. *Ascomycetes*: Spores borne within sacs (asci).
  - 1. *Discomycetes*: Asci borne on outer surface of open fructifications. Morels (*Morchella*, etc.)
  - 2. *Tuberaceæ*: Asci borne within subterranean tuberous fructifications. Truffles (*Tuber*, etc.)
- II. *Basidiomycetes*: Spores borne on the surface of sacs (basidia); usually 4 spores to each basidium.
  - 1. *Hymenomycetes*:
    - A. *Clavarieæ*: Basidia borne on the surface of branches. Coral Mushrooms (*Clavaria*, etc.)
    - B. *Hydneæ*: Basidia borne on spine-like projections. Spiny Mushrooms (*Hydnum*)
    - C. *Polyporeæ*: Basidia borne on the surface of pores or tubes. Tube-bearing Mushrooms (*Boletus*, *Fistulina*, etc.)
    - D. *Agaricineæ*: Basidia borne on radially arranged lamellæ (gills). Gill Mushrooms (*Agaricus*, *Coprinus*, etc.)
  - 2. *Gasteromycetes*: Basidia borne within closed fructifications. Puffballs (*Lycoperdon*, *Calvatia*, etc.)

CHEMICAL COMPOSITION.—Two substances of special interest in edible mushrooms are *urea* and the carbohydrate *trehalose*. *Muscarine*, $C_5H_{13}NO_2$ or $(CH_3)_3 \vdots N : (OH)CH_2CHO$, the aldehyde of choline, is an alkaloid occurring only in poisonous species.

Urea, $CO(NH_2)_2$, the well-known constituent of urine, occurs in various species of gill mushrooms, which see.

Trehalose or mushroom sugar, $C_{12}H_{22}O_{11} + 2H_2O$, is widely distributed in fungi, particularly various species of *Hymenomycetes*. The pure substance forms rhombic crystals of a sweet taste, melting at 97° C., readily soluble in water, much less so in alcohol (100 parts of hot alcohol). The specific rotation of the anhydrous substance is about +197°. It does not reduce Fehling solution and is not altered by the common enzymes but is hydrolyzed by trehalase present in certain fungi and with difficulty by boiling with dilute acid.

The trehalose of mushrooms, after gathering and especially during drying, is converted to a greater or lesser extent into *mannite*.

MORELS

(*Discomycetes*)

Fr. Morilles. It. Spugnolo. Ger. Morcheln.

THE morels, sometimes known as sponge mushrooms, appear early in the Spring and are widely distributed, occurring often in orchards or burned-over wood land. *Morchella esculenta* Pers. and *M. conica* Pers. are probably the best known, though other species are much esteemed.

MACROSCOPIC STRUCTURE (Fig. 1).—The thick *stalk* bears a more or less globular, club-shaped, or conical *head*, with a coarsely reticulated-indented exterior.

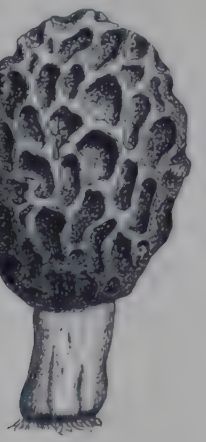

FIG. 1.

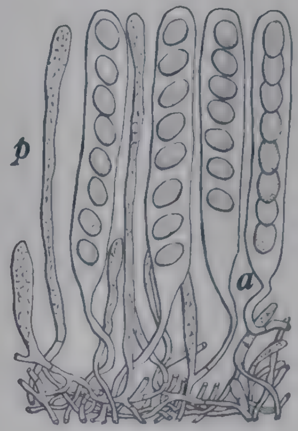

FIG. 2.

FIG. 1.—Morel. × ½. (K.B.W.)

FIG. 2.—Morel. Section of hymenium showing *a* asci with spores, and *p* paraphysis. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE (Fig. 2).—The *hymenium*, lining the indentations of the head, consists of closely packed club-shaped *asci* (*a*), each usually containing 8 oval *spores*. Interspersed with the asci are smaller sterile elongated bodies called *paraphyses* (*p*).

CHEMICAL COMPOSITION.—A single analysis of *M. esculenta* by Pizzi[1] and two at different stages of maturity by Mendel[2] follow:

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[1] Staz. sper. agr. ital. 1889, **17**, 167.

[2] Am. J. Physiol. 1898, **1**, 225.

COMPOSITION OF MORELS

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Pizzi.	89.07	3.59	2.39	0.27	5.73		1.34
Mendel:							
Immature. . .	91.24	2.93	. . . .	0.65	3.15	0.83	1.19
Mature.	89.54	3.05	2.28	0.50	4.90 *	0.42	1.09

* Soluble carbohydrates calculated as dextrose 1.60%.

Mineral Constituents.—The following analysis of the crude ash of *M. esculenta*, containing 1.41 per cent of charcoal, is by Pizzi:[1]

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	SiO_2	Cl	Sand	CO_2
%	%	%	%	%	%	%	%	%	%	%	%
20.22	7.84	3.92	2.40	6.68	3.12	22.82	8.52	6.27	4.15	8.31	2.42

[1] Loc. cit.

TRUFFLES

(*Tuberaceæ*)

Fr. Truffes. It. Tartufi. Ger. Trüffeln.

TRUFFLES are saprophytic and entirely subterranean, growing in Europe commonly in the open woods. They are very aromatic. The black or Périgord truffle (*Tuber melanospermum* Vitt.) is the choicest species and the one most frequently found on the market. Other species are less aromatic, while so-called white truffles (*Choiromyces meandriformis* Vitt., *Tuber album* Sow., and *T. magnatum* Pico) and false truffles (*Scleroderma* sp.) are markedly inferior.

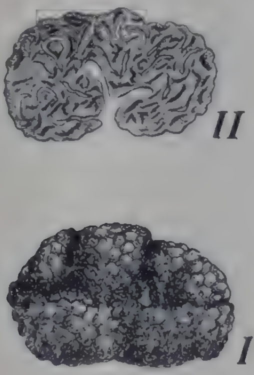

FIG. 3.

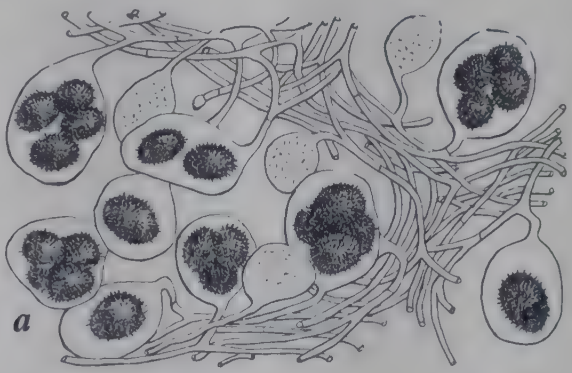

FIG. 4.

FIG. 3.—Black Truffle. *I* whole, *II* longitudinal section. × ½. (K.B.W.)
FIG. 4.—Black Truffle. Section of hymenium showing *a* asci with spores. × 160. (K.B.W.)

MACROSCOPIC STRUCTURE (Fig. 3).—The *tuber* of the black truffle is very dark in color and warty on the surface (I). A longitudinal section (II) shows that the dark color permeates all the tissues, that there is an opening at the base, and that air passages occur here and there through the tuber.

MICROSCOPIC STRUCTURE (Fig. 4).—The *hymenium* lining the air passages bears rounded stalked *asci* (*a*), each usually with four oval, spiny, and dark-colored *spores*. The length of the spores varies somewhat with the species, reaching 45 μ in black truffles, and in some species the spines are replaced by reticulations.

Falck[1] gives illustrations showing the spores of true and false truffles.

---

[1] Z. Unters. Nahr.-Genussm. 1911, **21**, 209.

CHEMICAL COMPOSITION.—Black or true Périgord truffles (*T. melanosporum* Vitt.) and white truffles (*T. magnatum* Pico.), as analyzed by Pizzi,[1] contained as follows:

Composition of Truffles (Pizzi)

	Water	Protein	Protein, pure	Fat	N-f. ext.*	Ash
	%	%	%	%	%	%
Black......	74.95	8.85	6.23	0.33	13.78	2.09
White......	78.59	8.53	6.04	0.47	10.61	1.80

* Includes fiber.

Mineral Constituents.—Pizzi's analyses of the crude ash of black and white truffles follow:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	SiO_2	Cl	Sand	CO_2	C
	%	%	%	%	%	%	%	%	%	%	%	%	%
Black	28.09	9.13	1.40	2.90	2.25	5.28	34.65	3.01	1.31	trace	6.18	1.48	2.36
White	26.59	11.49	1.77	2.17	2.53	6.88	33.18	4.18	1.06	0.73	1.17	2.66	3.47

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[1] Staz. sper. agr. ital. 1889, **16**, 737; 1889, **17**, 1.

COMMON MUSHROOMS

(*Hymenomycetes*)

This group, here arbitrarily designated "common mushrooms," includes the greatest number of edible species. As shown in the scheme given above, it is divided into four sub-groups, a representative of each of which is illustrated in Fig. 5. The general characters of the four sub-groups are described in the following sections.

All the species bear elongated basidia with sterigmata and spores at the tip.

I. CORAL MUSHROOMS

(*Clavarieæ*)

Ger. Hirschschwamm.

Coral mushrooms, appropriately named, are found in moist woods of both continents, often forming large masses. A few members of the next section (*Hydneæ*) resemble coral, but the term generally refers only to species of *Clavarieæ*.

MACROSCOPIC STRUCTURE (Fig. 5, I).—Irregular masses more or less profusely branched bear the spores on the ends of the smooth *branches.*

MICROSCOPIC STRUCTURE.—See Gill Mushrooms.

CHEMICAL COMPOSITION.—Von Loesecke[1] and Siegel[2] both quoted by König,[3] give analyses of red coral mushroom (*Clavaria botrytis* Pers.) and (dried?) yellow coral mushroom (*C. flava* Pers.) respectively as follows:

Composition of Coral Mushrooms

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Red.......	89.35	1.31	0.29	7.66	0.73	0.66
Yellow.....	21.43	19.19	1.67	47.00 *	5.45	5.26

* Mannite 6.13%.

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[1] Arch. Pharm. 1876 [3], 9, 133.

[2] Oekonom. Fortschr. 1871, 38.

[3] Chem. mensch. Nahr.-Genussm., Berlin, 1903, 1, 814.

II. SPINY MUSHROOMS

(*Hydneæ*)

Ger. Stoppelschwamm.

Spiny mushrooms are common in the woods, especially in Autumn. *Hydnum repandum* L. is a favorite both in Europe and the United States.

MACROSCOPIC STRUCTURE.—Although most of the species have a true *stalk* and *cap* (pileus) on the under side of which are pendent spines (Fig. 5, II), others are irregular in outline with or without a stalk and in a few cases resemble coral. The spores are borne on the spines.

MICROSCOPIC STRUCTURE.—See Gill Mushrooms.

CHEMICAL COMPOSITION.—The only available analyses are 3 by Pahl[1] summarized below:

Composition of *Hydnum repandum* (Pahl)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	87.78	0.73	0.20 *	2.66 *†	0.24 *	0.44
Max.	95.67	3.86	0.25 *	2.84 *‡	1.08 *	1.12
Aver.	**92.68**	**1.79**	**0.23 ***	**2.75 ***	**0.66 ***	**0.69**

* 2 analyses. † Sugar 0.94%. ‡ Sugar 1.24%.

III. TUBE-BEARING MUSHROOMS

(*Polyporeæ*)

The tube-bearing mushrooms grow in fields and woods. The cèpe (*Boletus edulis* Bull.) is collected in large quantities in Europe and is sold fresh and canned.

MACROSCOPIC STRUCTURE.—The species occurring most frequently have a *cap* (pileus) (Fig. 5, III) bearing on the under side numerous tubes or pores with closed inner and open outer ends. On breaking apart the cap, the color in some species changes abruptly and markedly. The "beef-steak fungus" (*Fistulina hepatica* Fries), one of the stalkless bracket forms growing on tree trunks, is much esteemed in both Europe and America.

MICROSCOPIC STRUCTURE.—See Gill Mushrooms.

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[1] Landtor, Akad. Hangling. Tidskr. 1878, 42; König: Chem. mensch. Nahr.-Genussm., Berlin, 1903, **1**, 814.

CHEMICAL COMPOSITION.—Analyses of *Boletus edulis* by Strohmer[1] and Stahl-Schröder[2] and one analysis of *Polyporus sulphureus* by Mendel[3] follow:

COMPOSITION OF TUBE-BEARING MUSHROOMS

	Water	Protein	Protein, pure	Fat	N-f. ext.	Mannite, dextrose, etc.	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Boletus:									
Strohmer.....	90.06	2.93*	2.30	0.51†	4.72	2.04	2.45	1.15	0.63‡
Stahl-Schröder	84.19	7.48	4.41	0.49	5.51	....	....	0.88	1.45
Polyporus:									
Mendel.......	70.80	6.00	4.07	0.93	19.26	3.56§	....	0.88	2.13

* Ammonia 0.015%, amino acids 0.34%, acid amides 0.56%. † Neutral fat 0.22%, free fatty acids 0.29%. ‡ P_2O_5 0.16%. § Soluble carbohydrates.

Compared with the stem on the dry basis, Strohmer[1] found that the cap contained about twice as much protein, one and one-half as much fat, four times as much ash, one and one-half as much phosphoric acid but a little less fiber.

Winterstein and Reuter[4] state that the composition of *Boletus edulis* is approximately: water 10 per cent; ether extract 4 per cent, containing fat 3.2 and cholesterol 0.5 per cent; alcohol extract 12 per cent, containing trehalose 3 per cent, sugars, lecithin, bases, purine bodies, amino acids, etc., 9 per cent; water extract 28 per cent, containing glycogen from viscosin 5 per cent and sugar, purines, bases, amino acids, ash, etc., 23 per cent; residue 46 per cent, containing protein 30 per cent, amorphous carbohydrates (paraisodextrane) 10 per cent, and chitin 6 per cent; all on the air-dry basis.

Water was shown by Sabalitschka and Riesenberg[5] to extract 6.7 per cent of the 14.8 per cent of dry matter and half of the 5.22 per cent of total nitrogenous matter. This loss is unnecessary since *Boletus*, unlike species of *Lactarius* and *Helvella esculenta*, contains no poisonous matter removed by boiling.

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[1] Arch. Hyg. 1886, **5**, 322.

[2] Selsk. Khoz. i Lyesov. 1897, **184**, 437.

[3] Am. J. Physiol. 1898, **1**, 225.

[4] Centr. Bakt. Parasintenk. 1912, II, **34**, 566.

[5] Ber. pharm. Ges. 1923, **33**, 12.

Proteins.—From the proteins Winterstein and Reuter[1] split off glycocoll, alanine, valine, leucine, aspartic acid, glutamic acid, phenylalanine, and proline.

Amino Acids and Nitrogenous Bases.—The above-named authors found in extracts of both fresh and dried mushrooms, made with various solvents, the following: *trimethylhistidine*, *adenine*, small amounts of *guanine* and *hypoxanthine*, traces of *leucine* and *phenylalanine*, *tetramethylendiamine*, *ammonia*, and *trimethylamine*; also a base ($C_9H_{15}O_2N_3$), later[2] identified as *histidine-betaine*. From the dried fungus, they isolated 5.28 per cent of "viskosin" containing 4.25 per cent of nitrogen in combination with glycogen, which on hydrolysis yielded purine bases (xanthine, etc.), but no pentose. After autolysis for several weeks they identified putrescine, isoamylamine, and trimethylhistidine.

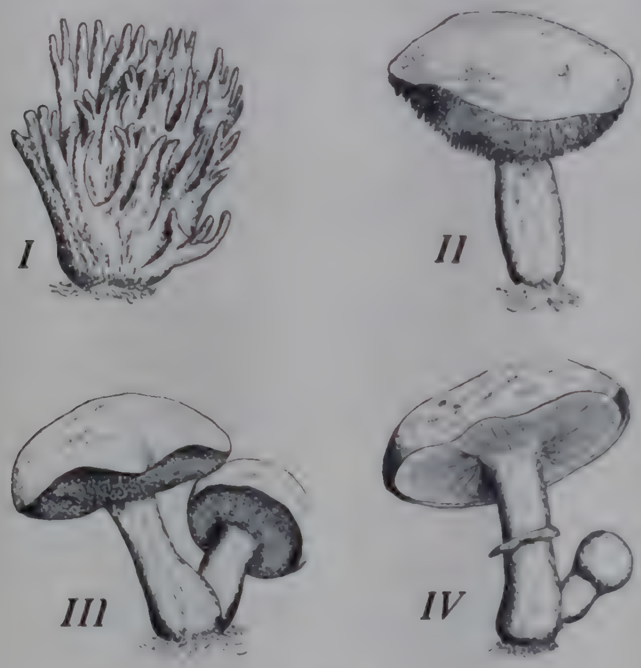

FIG. 5.

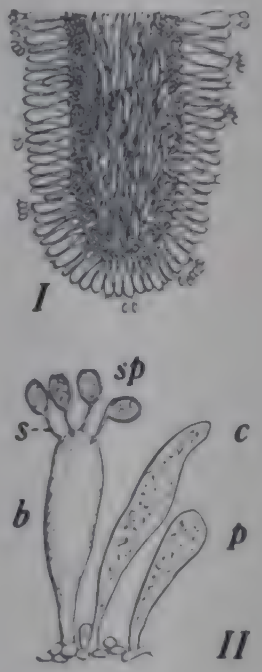

FIG. 6.

FIG. 5.—Hymenomycetous Mushrooms. *I* coral mushroom; *II Hydnum; III Boletus; IV* field mushroom. × ½. (K.B.W.)

FIG. 6.—Field Mushroom. *I* gill in cross section. × 160. *II* section of hymenium showing *b* basidium with *s* sterigmata and *sp* spores, *c* cystidium, and *p* paraphysis. × 480. (K.B.W.)

Yoshimura[3] found in air-dry *Boletus edulis* adenine 0.012, histidine 0.014, and trimethylamine 0.015 per cent, but no arginine or choline.

Color Reactions.—According to Van der Ven,[4] the blue color formed when *Boletus cyanescens* is broken is due to the action of the oxidase

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[1] Loc. cit.

[2] Z. physiol. Chem. 1913, **86**, 234.

[3] Z. Unters. Nahr.-Genussm. 1910, **20**, 153.

[4] Chem. Weekblad. 1915, **12**, 247.

laccase on muscarine. Sartory and Bertrand[1] have studied the colors formed in other species of *Boletus* by ammonia with the view of aiding in their identification.

Enzymes.—See Color Reactions above.

Mineral Constituents.—The following analysis (recalculated) of the pure ash of *B. edulis* is by Stahl-Schröder:[2] potash and soda 49.83, lime 3.86, magnesia 2.38, ferric and manganic oxides and alumina 2.15, phosphoric acid 24.74, sulphuric acid 14.08, and silica 0.57 per cent. The crude ash contained 2.29 per cent of carbon dioxide.

Minor Mineral Constituents. *Zinc.*—Whole 5.1 mg. per kilo, fresh basis (Bertrand and Benzon).[3]

IV. GILL MUSHROOMS

(*Agaricineæ*)

The meadow or field mushroom (*Agaricus campestris* L. = *Psalliota campestris* L.) is the species most commonly collected in the late Summer or Fall in grassy places, especially horse pastures. It is also grown extensively for the market on stable manure in cellars, abandoned mines, and special houses. Other gill-bearing mushrooms of the genus *Agaricus*, as well as of many other genera, are collected by enthusiasts in fields and forests, some being of the umbrella type and others more or less bracketed. Certain beautiful but deadly poisonous species of *Amanita* and other genera belong to this section which not only the collector but also the purchaser must learn to distinguish from the edible species.

MACROSCOPIC STRUCTURE.—The true field mushroom is shown in Fig. 5, IV. It first comes through the ground as a little globular " button," but as the *cap* (pileus) expands the delicate veil covering its lower part breaks, leaving a *ring* (annulus) around the *stalk* and exposing the pinkish gills radiating from the stalk. The ring should not be confused with the *volva*, a more or less developed cup-like structure at the base of the stalk, being especially well developed in poisonous species of *Amanita*.

MICROSCOPIC STRUCTURE (Fig. 6).—*Agaricus* may be taken as the type not only for the gill-bearing group but also for all *Hymenomycetes*, as the differences are not in the general shape of the spore-bearing basidia. Although sections show somewhat different arrangement of hyphæ in different species, the individual strands all consist of simple threads with occasional cross walls, these latter becoming more numerous in the *hymenium*, where the *basidia* (*b*) with their accompanying sterile *paraphyses* (*p*) and *cystidia* (*c*) are formed. The basidia are enlarged, elongated, club-shaped cells at the apex of which are produced 4 slender *sterigmata* (*s*), each bearing a single oval *spore* (*sp*) about 8 μ in length.

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[1] Compt. rend. soc. biol. 1914, **76**, 363.

[2] Loc. cit.

[3] Bul. soc. hyg. aliment. 1928, **16**, 457.

In *Lactarius* are found special branching hyphal tubes containing a milky juice.

CHEMICAL COMPOSITION.—Over half the nutritive matter is protein, the percentage being higher in young than in mature mushrooms and in the head than in the stem. This is evident from the following analyses of field mushrooms made at the New York State Agricultural Experiment Station[1] and by Zega[2] in Serbia:

COMPOSITION OF FIELD MUSHROOMS

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
N. Y. Station:							
Mature......	91.80	4.83	2.57	0.31	2.04		1.02
Buttons.....	90.33	5.62	3.23	0.30	2.60		1.15
Zega:							
Large							
Head (69 g.)	90.72	5.84	....	0.34	1.62	0.71	0.77
Stem (39 g.)	86.81	6.12	....	0.21	4.82	1.00	0.94
Whole (90g.)	90.74	4.92	....	0.26	2.45	0.84	0.59
Medium							
Head (16 g.)	88.15	7.30	....	0.20	2.77	0.85	0.73
Stem (24 g.)	87.12	6.34	....	0.12	4.74	0.87	0.81
Whole (55g.)	91.87	4.31	....	0.23	2.16	0.88	0.55
Small							
Whole (18g.)	88.12	7.10	....	0.32	3.12	0.56	0.78

Analyses of various American species of gill-bearing mushrooms by Mendel,[3] of a dried Indian species by Hooper,[4] and of two species of *Amanita*, said to be harmless after removal of the skin, by Düring[5] follow:

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[1] Rep. 1894, p. 134.

[2] Chem. Ztg. 1900, **24**, 285.

[3] Am. J. Physiol. 1898, **1**, 225.

[4] Chem. News 1911, **104**, 145.

[5] Pharm. Zentralh. 1926, **67**, 693.

Composition of Various Gill Mushrooms

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Mendel:							
Coprinus comatus	92.19	2.82	0.94	0.26	3.17*	0.58	0.98
Pleurotus ostreatus	73.70	3.94	1.85	0.84	17.95†	1.97	1.60
Clytocybe multiceps	93.49	2.18	0.80	0.39	2.57	0.62	0.75
Hypholoma condolleanum	88.97	2.95	1.71	0.28	4.94	1.33	1.53
Hooper:							
Pleurotus cretaceus	12.25	21.25	.....	....	.....	3.05	8.75‡
Düring:							
Amanita rubescens Pers.	93.85	2.26	.....	0.35	.....	0.69	0.81
Amanita spissa Fries	93.63	2.60	.....	0.28	.....	0.92	0.80

* Soluble calculated as dextrose 1.40%. † Soluble calculated as dextrose 4.89%. ‡ Phosphoric acid 1.85%.

Nitrogenous Bases.—Kutscher[1] isolated from a water extract of field mushrooms small amounts of *arginine*, *choline*, *betaine*, and what appeared to be histidine with three methyl groups added, later shown by Winterstein and Reuter to be *histidine-betaine* (see *Boletus*).

Urea.—According to Ivanov,[2] amino acids are formed autolytically during ripening and before spore formation, then these are changed into urea. As a result of a generous supply of nitrogen, urea may reach as high as 13 per cent of the dry weight of field mushrooms, equivalent to about half of the total nitrogen.

Ivanov and Toshevikova[3] found that urea is formed in the mushroom from arginine naturally present and in mushroom juice from added arginine. It is also synthesized from ammonium carbonate by an oxidation process in the living cells of the mushroom, even after separation from the mycelium. Ivanov and Smirnova[4] demonstrated that urea in mushrooms, like asparagine in higher plants, is formed only in the presence of oxygen. Salts of ammonia appear to be toxic if not converted into urea.

Fat. *Sterols.*—Various edible fungi, examined by Sumi[5] contained 0.1 to 0.4 per cent of ergosterol calculated to the dry basis.

Acids.—The genus *Lactarius* is characterized by the presence of

[1] Zentr. Physiol. 1910, **23**, 775.

[2] Biochem. Z. 1923, **143**, 62.

[3] Ibid. 1927, **181**, 1.

[4] Zhur. exptl. Biol. Med. 1929, **11**, 79.

[5] Bul. inst. Phys.-Chem. Res. (Tokyo), 1932, **11**, 120.

lactarinic acid, a 6-ketostearic acid ($CH_3(CH_2)_{11}CO(CH_2)_4CO_2H$), and *stearic acid,* the latter being the lactaric acid of earlier investigators.

Lactarinic Acid.—Bougault and Charaux[1] found in *L. uvidus* Fr. 2.9, in *L. theiogallus* B. 2.3, in *L. lilacinus* Lasch. 2.25, in *L. subdulcis* B. (var. *pale*) 2.15, in *L. plumbeus* B. 2.10, and in *L. pyrogallus* B. 1.80 per cent.

Stearic Acid.—The above-named authors found in *L. azonites* B. 3, in *L. vellereus* Fr. 1.2, in *L. controversus* Fr. 1.1, and in *L. deliciosus* L. 0.90 per cent.

Carbohydrates.—Experiments by Tikhomirov[2] indicate that *glycogen* formed in the young tissues is converted into *trehalose* which in turn through the agency of the trehalase of Bourquelot is converted into *dextrose.*

Glucosides.—A simple color test for field mushrooms or foods containing them, depending on the presence of *indican,* has been developed by Löury.[3] The indican is believed to be formed from substances contained in the manure in which the mushrooms are grown. On carefully pouring concentrated sulphuric acid over a water extract of the mushrooms a deep violet color forms at the juncture. Greater delicacy is secured by using concentrated hydrochloric acid containing a crystal of ammonium sulphate.

Enzymes.—Ivanov, Dodonowa, and Tschastuchin,[4] in *A. campestris,* identified *amylase, maltase, glycogenase, protease,* and *catalase,* but no sucrase, inulase, or urease. Amylase was much more active than maltase. *Lepiota procera* and *Coprinus radiatus* were also studied.

Mineral Constituents.—The analysis of *A. campestris* quoted by König appears to be low in phosphoric acid but high in sulphuric acid. The following analysis (recalculated) of the pure ash of *A. deliciosus* by Stahl-Schröder[5] is believed to represent the group better: potash and soda 58.51, lime 1.35, magnesia 2.11, ferric and manganic oxides and alumina 1.20, phosphoric acid 24.97, sulphuric acid 2.71, and silica 0.91 per cent. The amount of soda was doubtless trifling. The alkalinity of the crude ash is shown by the presence of 11.1 per cent of carbon dioxide.

Minor Mineral Constituents. *Iron.*—Mushrooms 31.4 mg. per kilo, fresh basis (Peterson and Elvehjem).[6]

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[1] J. pharm. chim. 1912, **5**, 65.

[2] Arch. Pharm. 1908, **246**, 582.

[3] Chem. Ztg. 1909, **33**, 1251; 1910, **34**, 340.

[4] Fermentforschung 1930, **11**, 433.

[5] Selsk. Khoz. i. Lyesov. 1897, **184**, 437.

[6] J. Biol. Chem. 1928, **78**, 215.

Aluminum.—*Agaricus campestris*, none (Bertrand and Lévy).[1]

Copper.—Mushrooms 17.9 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[2]

Zinc.—Whole *Agaricus* 2.8, whole *Cantharellus cibarius* Fr. 12.4 mg. per kilo, fresh basis (Bertrand and Benzon).[3]

Arsenic.—Mushrooms 0.06 mg. per kilo, fresh basis (Jardin and Astruc).[4]

Iodine.—Three varieties, none (Winterstein).[5]

PUFFBALLS

(*Gasteromycetes*)

Fr. Vesse-de-loups. It. Vescia. Ger. Bovist.

THE puffballs are saprophytic and common everywhere.

MACROSCOPIC STRUCTURE (Fig. 7).—The fructifications occur singly or in clusters and vary greatly in size from that of a small nut to a foot or more in diameter, a single specimen of one of the larger forms being sufficient for a family. They are globular or elongated with or without suggestion of a stalk. They are eaten only when immature, firm, and white inside; as maturity approaches the whole interior becomes filled with dry, powdery, dark spores which eventually escape in clouds as the top opens.

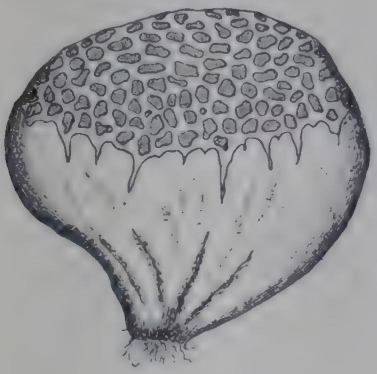

FIG. 7.

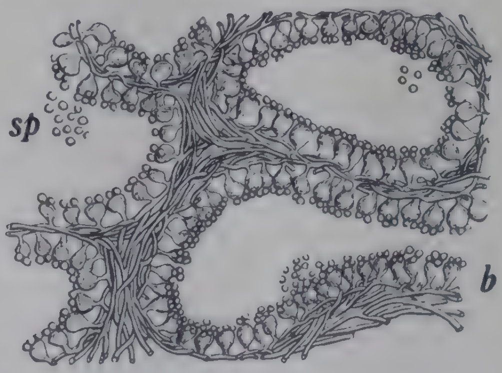

FIG. 8.

FIG. 7.—Puff Ball. × ½. (K.B.W.)

FIG. 8.—Puff Ball. Section of hymenium showing *b* basidia, and *sp* spores. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE (Fig. 8).—A section through the immature puffball shows ramifying, connected openings lined with the

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[1] Bul. soc. hyg. aliment. 1931, **19**, 359.

[2] J. Biol. Chem. 1929, **82**, 465.

[3] Bul. soc. hyg. aliment. 1928, **16**, 457.

[4] Compt. rend. 1912, **155**, 291.

[5] Z. physiol. Chem. 1918, **104**, 54.

hymenium, each of the rounded *basidia* (*b*) bearing usually four minute, rounded, white *spores* (*sp*). It is only when beyond the edible stage that the spores darken.

CHEMICAL COMPOSITION.—Analyses of *Lycoperdon Bovista* L. by Von Loesecke[1] and by Pahl,[2] both quoted by König,[3] follow:

COMPOSITION OF LYCOPERDON BOVISTA

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Von Loesecke.....	86.92	6.62	0.41	3.42	1.43	1.20
Pahl.............	87.02	7.84	0.37	1.68*	2.34	0.85

* Sugar 1.34%.

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[1] Arch. Pharm. 1876, [3], **9**, 133.

[2] Landtbr. Akad. Handling. Tidskr. 1878, 42.

[3] Chem. mensch. Nahrs.-Genussm., Berlin, 1903, **1**, 816.

ROOT VEGETABLES

Roots of dicotyledonous plants, which in the state of nature are slender and woody, are by selection and breeding so modified as to be fleshy and tender.

MACROSCOPIC STRUCTURE.—The ideal form of the typical root consists almost entirely of an enlarged *taproot*; if for any reason this splits up into several branches, the product is inferior because of the losses in paring. In the sweet potato, vetchling, yam bean, ground nut, and kudzu, the edible parts are enlargements of the roots known as root tubers, analogous to true tubers which are enlargments of subterranean stems. Cross sections of roots show various markings, but the cambium layer in all is clearly evident to the naked eye. This may be near the surface (turnip and radish) or one-third to one-half the distance from the surface to the center (carrot and parsnip). In the beet there are a number of cambium layers forming concentric rings.

MICROSCOPIC STRUCTURE.—Excepting the beet, the layers are: (1) *cork* of a variable number of layers, (2) *cortex*, varying in thickness with the species, (3) *phloem zone*, (4) *cambium zone*, and (5) *xylem* extending to the center of the root. No endoderm or demarcation between the cortex and phloem is usually evident.

The arrangement of the tissues differs from that of aerial and subterranean (tubers, rhizomes, and corms) stems in that there is no pith, the xylem elements extending to the very center of the root; furthermore, the vessels are mostly of the pitted or reticulated type, whereas in edible stems they are largely spiral or modifications of the spiral type. The transition from one type of vessel to the other is observable in the crown of roots. In the very young root the *fibro-vascular bundles* are radial, that is xylem and phloem strands alternate, but soon the arrangement changes to collateral, that is the phloem and xylem of each bundle are in the same radial longitudinal plane.

Latex tubes are abundant in the phloem of roots of convolvulaceous, campanulaceous, and composite plants. *Reserve starch* occurs in certain garden roots, *inulin* in others.

Family characteristics based on the writers' studies, which it is believed will prove of fundamental importance in chemical studies of the groups, are listed below:

Chenopodiaceæ: several concentric cambium zones; sucrose and related carbohydrates, also coloring matter, dissolved in cell sap; starch absent (e.g., beet).

Cruciferæ: sulphur compounds present; starch may or may not be present (e.g., radish, turnip, horse-radish).

Leguminosæ: starch and monoclinic crystals (in crystal fibers) present; latex occurs in ground nut.

Umbelliferæ: volatile oil present; starch present during growing season, passing into sugar in Fall or after wintering in the ground; chromoplasts in yellow and orange roots (e.g., carrot, parsnip).

Convolvulaceæ: starch, oxalate rosettes, and latex present (e.g., sweet potato).

Campanulaceæ: latex present.

Compositæ: starch absent; inulin and latex present (e.g., salsify, great burdock).

ROOTS OF THE GOOSEFOOT FAMILY

(*Chenopodiaceæ*)

BEET root stands alone in the family as a root vegetable. Beet leaves and spinach have thickened petioles which contribute to their value as greens.

Nitrogen as *pure protein* makes up about half the total nitrogen of beet root. *Nitric nitrogen* may reach or exceed half the nitrogen as pure protein. *Sucrose* is the chief constituent. Various other carbohydrates are present.

BEET ROOT

Beta vulgaris L. var. *crassa* Alef.

Fr. Betterave. Sp. Acelga. It. Bietola. Ger. Runkelrübe.

De Candolle states that the wild form of the beet occurs native throughout the Mediterranean region and southwestern Asia. Food plants assigned to the same species are: (1) Garden Beets, (2) Mangel-Wurzels, (3) Sugar Beets, and (4) Chard (which see). Foliage beets, grown as ornamentals, are varieties of the species.

Roots of the garden beets are of moderate size and are at their best when young and tender. The plants at an earlier stage, pulled in thinning out the rows, are used as greens (see Beet Greens). Mangel-wurzels (mangolds, mangels) and sugar beets grow to enormous size and, except when young, are too coarse in texture for human food, but both forms in the succulent state are highly esteemed for cattle feeding as are also shredded dried sugar beets from which the sugar has been extracted on a commercial scale.

MACROSCOPIC STRUCTURE.—Garden beets are commonly deep red but there are also yellow and white varieties. Mangel-wurzels and sugar beets are commonly whitish or yellowish. The shape varies from elongated tapering to flattened top-shaped. When young the form is quite symmetrical but later longitudinal depressions form, large specimens being irregular in shape. The surface in the part of the root proper that rises above the ground is coarsely granular, becoming roughened at the base of the leaves; the surface beneath the soil is granular with rootlets in the depressions and especially on the long narrow terminal.

A cross section of a red beet (Fig. 9) shows the remarkable alternating light and dark concentric rings. The light rings consist of zones of bundles, each consisting of phloem, cambium, and xylem elements, the latter predominating. Separating the light rings in the red beet are zones rich in deep red cell sap. Growth is due to the activity, not of a single cambium layer, but of as many such layers as there are light rings, and the size of the root is due more to the thickness of the zones than to their number.

De Vries[1] discovered that traces from different rings pass to the same leaf. Artschwager[2] found that the ring-density coefficient is an index of sucrose content except where the number or width of the rings shows no correlation. Roots with broad vascular zones and high ring-density coefficient are usually high in sugar. A higher number of rings and relatively smaller core and first ring are apparently associated with an increase in sugar content.

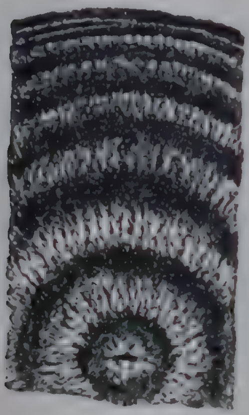

FIG. 9.—Beet Root. Cross section showing rings; outer light ring partly split. × 1. (A.L.W.)

MICROSCOPIC STRUCTURE.—Wiesner[3] was the first to give an accurate description of the histological structure of the root, and Droysen[4] and De Vries[5] later studied its development as well as its histology. Artschwager[6] describes the structure and development of all the vegetative organs in a copiously illustrated article. Among those who have studied the relation of structure to sugar content are Geschwind,[7] Peklo,[8] and Artschwager.[9] Moeller[10] and Vogl[11] describe certain tissues with reference to the detection of beet residues in chicory and coffee.

Although *starch* does not occur in normal sugar beets, Peklo[12] states that cut or injured beets show starch beneath the wound. He believes that its formation may be due to the concentration of the sugar at such points. Kopuil-Gomolyako[1] calls attention to the presence of *oil* in the root, particularly in the peripheral layers and at full maturity. He found *starch* only in roots of the mangold type.

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[1] Landw. Jahrb. 1879, **8**, 417.

[2] J. Agr. Res. 1930, **40**, 867.

[3] Techn. Mikros., Wien, 1867, p. 247; Rohstoffe, Leipzig, 1873, p. 640.

[4] Beitrage z. Anat. u. Entwicklung der Zuckerrübe, Halle, 1877.

[5] Loc. cit.

[6] J. Agr. Res. 1926, **33**, 143.

[7] Bul. ass. chim. sucr. dist. 1901, **18**, 785.

[8] Oester.-Ungar. Z. Zuckerind. Landw. 1908, **37**, 153.

[9] J. Agr. Res. 1930, **40**, 867.

[10] Mikros. Nahr.-Genussm., Berlin, 1 Aufl. 1886, p. 290.

[11] Wicht. Nahr.-Genussm., Berlin, 1899, p. 339.

[12] Z. Zuckerind. Böhmen 1909, **33**, 438.

Microchemical examination of the osazones by Strakosch[2] indicates that the mesophyl of the leaf pulp contains only dextrose which is translocated to the veins where levulose first appears, followed by the formation of sucrose from the two monosaccharides. Finally the *sucrose* is moved to the root.

Cork.—Several layers of tabular cells (Fig. 10, *S*) form a protective coat much ruptured during growth. In surface view (Fig. 11, *su*) the cells are polygonal, isodiametric, or slightly elongated, reaching 100 μ in their maximum diameter.

Hypoderm.—This includes the cells of the *phellogen layer*, forming cork on the outer and parenchyma on the inner side. These tissues may also be regarded as outer cortex. As shown in cross and longitudinal sections, the cells are tabular. In surface view (Fig. 11, *hy*) they are longitudinally elongated, often nearly quadrilateral, arranged in transverse rows. Red coloring matter fills the cells of this layer as well as of the cortex.

Cortex (Fig. 10, *C*).—Longitudinal sections show the transition from tabular

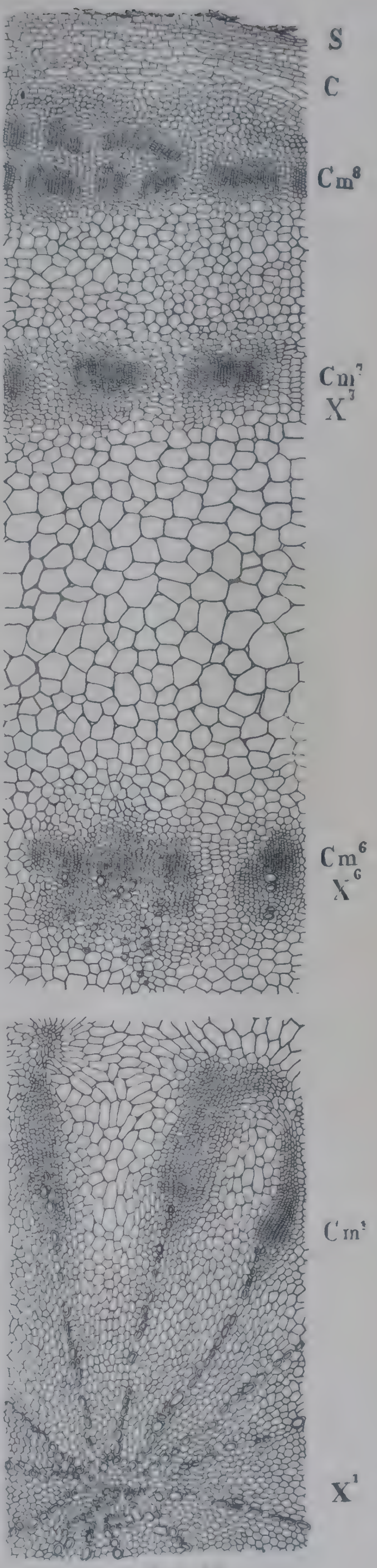

FIG. 10.

FIG. 10.—Beet Root. Magnified cross section. *S* cork; *C* cortex; X^1 central (primary) xylem with vessels extending to cambium ring Cm^1; X^6 and X^7 xylem formed by cambium rings Cm^6 and Cm^7. Vessels formed by cambium ring Cm^8 not well differentiated. × 26. (A.L.W.)

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[1] Nauk. Zapiski Tzukrovoi Prom. 1933, **10**, No. 33, 91; Chem. Abs. 1934, **28**, 2746.

[2] Oesterr. ung. Z. Zuckerind. 1912 **41**, 224.

to isodiametric cells. The inner cortex with its rounded polygonal cells corresponds to the parenchyma forming the dark zones separating the light-colored bundle zones. The cells of the parenchyma zones at earlier stages of development, before they were separated from the outer cortex by the formation of new bundle zones, were of correspondingly smaller size. Longitudinal sections of young beets of table size show that the parenchyma cells not only of the cortex but also of the phloem, xylem, and parenchyma zones are arranged side by side in radial rows. At that stage both endoderm and pericycle have lost their identity.

Phloem Rings.—In addition to *sieve tubes* and *companion cells* in a *ground parenchyma*, the adjacent cells of which are elongated, here and there are present cells containing a mass of *crystal sand*. On breaking up the masses, the minute individual oxalate crystals are seen to be triangular or diamond-shaped.

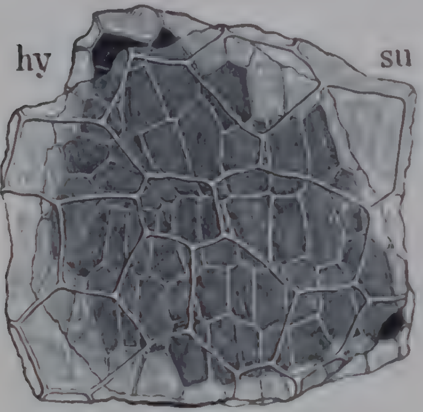

FIG. 11.

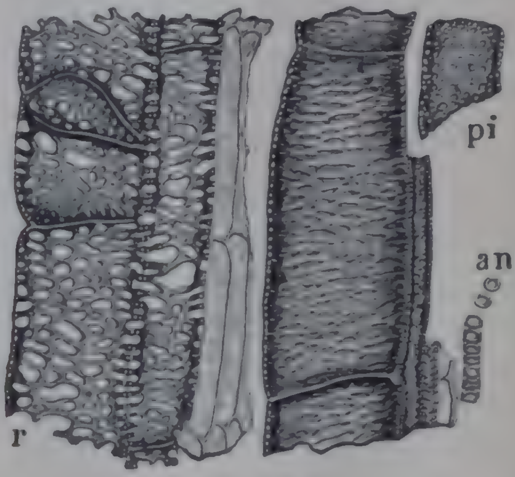

FIG. 12.

FIG. 11.—Beet Root. *su* cork and *hy* hypodermal parenchyma with deep red cell sap in tangential section. × 160. (A.L.W.)

FIG. 12.—Beet Root. *r* reticulated, *pi* pitted, and *an* annular vessels in longitudinal section. × 160. (A.L.W.)

Cambium Rings (Fig. 10, *Cm*, numbered in order of formation).—In the bundle rays the cells are small; in the medullary rays they are much larger.

Xylem Rings (Fig. 10, *X*, numbered to correspond with cambium rings).—As shown in Fig. 12, the *vessels* vary greatly in breadth (7 to 100 μ), length of joints, and character of the thickening. In addition to numerous vessels variously reticulated (*r*) or pitted (*pi*), occasional narrow spiral or annular vessels (*an*) occur in the root proper. At the top, where the root passes into the neck which is morphologically stem, the reticulated and pitted vessels pass into spiral-reticulated or true spiral forms, often reaching 60 μ in breadth.

Vessels are particularly abundant and varied in character in the ight-colored core (Fig. 9), which consists of the primary diarch bundle, he primary medullary rays, and the later-formed xylem and medullary rays up to the first dark red zone consisting entirely of parenchyma.

Fibers, some broad (up to over 50 μ), others narrow (less than 10 μ), approaching bast fibers in appearance, accompany the vessels of mature beets, particularly sugar beets and mangel-wurzels, but are not noticeable in garden beets at the edible stage. They reach 1 mm. or more in length and have thin walls and diagonal pores.

Medullary rays separate the individual bundles of the bundle zones.

Parenchyma Zones.—In the red beet the cells of these zones for the most part contain a deep red sap while in colorless or yellow beets they are recognized by a shade somewhat different from that of the bundle zones. As was noted by Droysen, the tissue grows by cell division not only in the cambium layer but also in parts remote from that layer. Medullary rays are not clearly evident. The *sucrose* of the beet is located mostly in the sap of this parenchyma, hence high sugar production is associated with its robust development, a point of great significance. Sodium hydroxide solution added to a section changes the red coloring matter first to blue-red and then to golden yellow.

CHIEF STRUCTURAL CHARACTERS.—Root tapering or top-shaped, roughened or granular on surface. Cross sections show alternate dark and light zones.

In surface view, cork cells large, polygonal, hypoderm cells polygonal, approaching quadrilateral. Cortex and parenchyma zones (usually dark red) of cells in radial rows as seen in longitudinal section; bundle zones (light) several, each with a cambium layer. Vessels up to 100 μ, mostly pitted or reticulated, often with wide meshes; broad spiral vessels only at top near leaf bases.

CHEMICAL COMPOSITION.—Garden beets grown for the table and mangel-wurzels grown for stock feeding, although distinctly sweet, contain much less sucrose than sugar beets scientifically bred for sugar production. The American analyses summarized below from Jenkins and Winton's Compilation[1] were made when beet-sugar production in the United States was in its infancy.

Numerous determinations of solids and sucrose in American sugar beets, reported by Wiley,[2] show, in some states at least, a sugar content comparing favorably with that of the European product as is indicated by the range of the averages by states given below. The percentages of

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11**.

[2] U. S. Dept. Agr., Div. Chem. 1891, Bul. **33**; 1892, Bul. **36**.

COMPOSITION OF AMERICAN BEETS

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Garden beets:	8						
Min.		85.49	1.11	0.06	3.84	0.61	0.74
Max.		92.16	1.73	0.23	11.26	1.69	1.38
Aver.		**88.47**	**1.53**	**0.14**	**7.94**	**0.88**	**1.04**
Mangels:	9						
Min.		86.92	1.02	0.06	2.40	0.60	0.82
Max.		94.41	1.89	0.51	8.67	1.25	1.36
Aver.		**90.85**	**1.39**	**0.16**	**5.68**	**0.87**	**1.05**
Sugar beets:	19						
Min.		80.47	1.12	0.05	5.67	0.64	0.42
Max.		90.76	3.15	0.22	13.58	1.26	1.45
Aver.		**86.50**	**1.75**	**0.10**	**9.89**	**0.88**	**0.88**

sugar given in the table are those in the beet; calculated to the juice they are about 5 per cent higher.

	Number of states	Number of growers	Solids	Sucrose
			%	%
1891	36	1225		
Min.	....	....	10.91	6.37
Max.	....	....	20.47	17.20
1892	29	211		
Min.	....	....	12.10	8.09
Max.	....	....	20.00	15.92

In 1891 the state showing the highest average content of both solids and sucrose was Nevada; the state showing the lowest content of solids was New Jersey, and the lowest content of sucrose was Oklahoma. In 1892, California beets had the highest content of solids but Nevada beets again had the highest sucrose content while Kentucky and Maryland beets respectively had the lowest content of solids and sucrose. Generalizations should not be based on these figures since in nearly all instances they represent only a few growers. Wisconsin beets, represented by 402 growers in 1891, contained on the average 15.35 per cent of solids and 11.05 per cent of sucrose, and Iowa beets, represented by 214 growers during the same year, contained 16.32 per cent of solids and 11.82 per cent of sucrose.

Determinations made by Pitsch[1] on Yellow Globe, Golden Tankard, and Fodder Sugar Beets, grown on the same field, gave on the dry basis respectively: protein 7.69, 8.75, 7.50; fat 0.48, 0.58, 0.70; nitrogen-free extract 79.11, 77.15, 78.61; sucrose 58.73, 60.17, 64.82; fiber 6.67, 6.33, 6.70; ash 8.12, 7.36, 7.74; protein nitrogen 0.57, 0.65, 0.64; nitric nitrogen 0.33, 0.08, 0.20; other nitrogen 0.33, 0.67, 0.36; total nitrogen 1.23, 1.40, 1.20 per cent.

The general nature of the water-insoluble substances contained in the beet is shown by an analysis by Street[2] of the dried pulp used for stock feeding as follows: water 9.86, protein 6.94, fats, waxes, resins, colors 1.89, reducing sugars as dextrose 1.21, invert sugar as sucrose 7.10, araban 19.61, galactan 8.30, pectin 2.17, parapectin 0.90, hemicellulose (includes galactan) 16.16, cellulose 11.32, lignin acids 6.99, lignin 6.21, organic acids 5.23, tannin 0.12, ash 4.08, undetermined 0.73. Six different modifications of araban and not less than three of galactan were identified.

Influence of Heredity and Season on Composition.—Analyses by Shutt[3] of two well-marked varieties of mangels, grown side by side for 11 years, show the composition as influenced by heredity and seasonal environment, a summary of the results being as follows: Gate Post, solids 9.41 to 13.90, aver. **11.90**, sucrose in juice 4.15 to 9.39, aver. **6.47**; Giant Yellow Globe, solids 7.80 to 12.73, aver. **9.93**, sucrose in juice 2.64 to 6.45, aver. **4.79** per cent.

Influence of Locality on Composition.—The variation in composition attributable to place of growth is well illustrated by analyses by Shutt[4] of sugar beets of 3 varieties grown during the year 1910 in different sections of the Dominion of Canada, extending from the Atlantic to the Pacific, and representing widely different conditions of soil, elevation, atmosphere, and temperature. The range of solids was Vilmorin Improved 17.37 to 21.89, Klein Wanzleben 16.63 to 22.09, Très Riche 15.40 to 22.19; the range of sucrose was Vilmorin Improved 13.40 to 19.92, Klein Wanzleben 12.94 to 20.08, Très Riche 11.73 to 17.55 per cent.

Composition of Different Parts of the Root.—The sugar content is greatest midway between the tip and the lower end and in the inner portion of the root. Small beets contain higher percentages of sugar than large ones. Milne, Jones, and Willcox[5] note that the crown is

[1] Landw. Vers.-Stat. 1892, **21**, 471.

[2] New Jersey Agr. Exp. Sta. Rep. 1906, p. 39.

[3] Can. Dept. Agr., Rep. Dom. Chem. 1911, p. 176.

[4] Loc. cit.

[5] J. Soc. Chem. Ind. 1931, **50**, 155T.

poorer in sugar but richer in nitrogen, fiber, and ash than the remainder of the root; also that a green coloration on the exposed part is associated with a slight decrease in sugar.

Influence of Culture on Composition.—Fagan and Watkin[1] found that when sown early the roots of 4 out of 5 varieties of mangels examined contained lower percentages of dry matter and lower percentages of sugar and protein in the dry matter than when sown later.

Influence of Fertilizers on Composition.—Many experiments have been carried out along this line. Results by Fagan and Watkin[2] show that nitrogenous fertilizers increase the percentage of protein in the dry matter, ammonium salts reduce the percentage of dry matter and sugar in the root, and potassium salts narrow the ratio of true to crude protein. By the application of 40 per cent potash salts and kainite, Decoux[3] increased the sugar content several per cent without appreciably increasing the saline quotient of the juice.

Changes in Composition During Storage.—According to Fagan and Watkin,[4] when mangels are stored in heaps the percentage of dry matter and sugars decreases while that of protein increases.

Milne, Jones, and Willcox[5] found that storage in heaps for two months reduced the sucrose content 2.5 per cent.

Harwood and Martin[6] record an increase in reducing sugars in mangels from 0.17 on December 19 to 1.66 per cent on March 12 with corresponding decrease of solids and sucrose.

Nitrogen Distribution.—Balboni and Valli[7] found in freshly sliced sugar beets (cossettes): total N 0.241, nitric N 0.003, albuminous N 0.086, amide and ammonia N 0.037, and "harmful" N 0.115 per cent. They also give results on the various juices and pulps of the process of manufacture.

Proteins.—No data on the nature of the proteins of beet root are available.

Amino Acids.—Among the substances identified in molasses by Von Lippmann,[8] some if not all of which are decomposition products formed during the manufacture of beet sugar, are *glutamic acid*, *aspartic acid*, and *arginine*. Smolenski[9] found no tyrosine or lysine.

[1] Welsh J. Agr. 1928, **4**, 102.

[2] Loc. cit.

[3] Ernähr. Pflanze 1932, **28**, 117.

[4] Loc. cit.

[5] Loc. cit.

[6] J. South-Eastern Agr. Col. Wye, 1928, **25**, 200.

[7] Ind. saccar. ital. 1930, **23**, 528; Facts About Sugar 1931, **26**, 221.

[8] Bul. ass. chim. sucr. dist. 1897, **14**, 691, 819.

[9] Z. ver. deut. Zuckerind. 1912, **62**, 791.

Purines.—Von Lippmann[1] also reported the presence of the following purine bases: *xanthine*, *guanine*, *hypoxanthine*, *adenine*, and *carnine*. According to Smolenski,[2] *allantoine*, a substance related to the purines, is a normal constituent of Russian beets. In the juice he found 0.005 per cent.

Nitrates.—Like turnips and various other roots, beets contain nitric acid believed to be combined with potash as saltpeter (potassium nitrate).

Continuing the experiments of H. and E. Schulze,[3] E. Schulze[4] obtained the following percentages: fodder beets, protein 5.44 to 11.54 dry basis and 0.55 to 1.21 fresh basis, N_2O_5 0.37 to 3.13 dry basis and 0.043 to 0.285 fresh basis; sugar beets, protein 4.88 to 8.56 dry basis and 0.83 to 1.24 fresh basis, N_2O_5 0.76 to 1.09 dry basis and 0.013 to 0.016 fresh basis.

See also Pitsch above.

Choline Bases.—The presence of *betaine* has been well established. Staněk[5] reports 0.95 to 1.20 per cent in the root and 2.62 per cent in the leaves. It is particularly abundant in the young leaves and is believed to take part in nitrogen metabolism. Smolenski[6] found up to 0.2 per cent of betaine in Russian beets. Staněk[7] in his method for the determination of betaine provides for removal of choline, which he evidently believed to be present; Smolenski, however, found no choline.

Amides and Other Nitrogenous Substances.—*Asparagine* has been reported by Schulze and others. Smolenski[6] separated 0.01 per cent of asparagine and 0.005 per cent of allantoine from the juice of Russian beets. In his earlier work[8] he identified also *glutamine* (previously detected by Schulze) and *vernine*; in his later paper neither glutamine, vernine, tyrosine, choline, trigonelline, nor lysine could be found in the juice then examined. He states that the presence of asparagine and allantoine and the absence of glutamine appear to be characteristic of Russian beet juice, especially in dry seasons, while glutamine is usually present in German, Austrian, and French beets. Vernine, when present, appears to be a decomposition product of nucleo-protein. Von Lippmann[9] mentions *guanidine*, *allantoine*, *vicine*, *vernine*, *vanillin*, and *alloxanthine*.

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[1] Bul. ass. chim. sucr. dist. 1897, **14**, 961, 819.

[2] Z. ver. deut. Zuckerind. 1912, **62**, 791.

[3] Landw. Vers.-Stat. 1867, **9**, 434.

[4] Ibid. 1872, **15**, 170.

[5] Z. physiol. Chem. 1911, **72**, 402.

[6] Loc. cit.

[7] Z. Zuckerind. Böhmen 1913, **37**, 385.

[8] Z. Ver. deut. Zuckerind. 1910, **60**, 1215.

[9] Loc. cit.

Porphyrin.—According to Fischer and Schwerdtel,[1] porphyrin is present in beets.

Fat.—The ether extract of mangels, examined by Neville,[2] contained free fatty acids consisting chiefly of: palmitic acid 8.7, oleic acid 36.1, and erucic acid 18.6 per cent. Triglycerides were also present.

According to Pavlas,[3] fat occurs in droplets in the cells. The following results were obtained on the ether extracts excepting those on the raw beet which were on the ether-alcohol extract of the ground material.

	Sp. gr.	Ref. index 21° C.	Sapon. No.	Iodine No.	Un-sapon. Matter	N Total	P_2O_5	Lecithin	Sterols
					%	%	%	%	%
Raw beet........	0.9737	1.5022	123.5	78.4	42.2*	0.097	0.064	0.73	11.41
Diffusion liquor...	0.9182	1.4865	91.9	71.2	43.7†	0.234	0.137	1.56	10.33
Beet residues.....	0.9673	1.5034	135.7	50.9	38.6	0.107	0.015	.....	9.83
Sediment in heaters	......	1.5030	97.2	64.6	57.3	0.130	......	.....	15.24
Sediment in tanks.	......	1.5035	80.6	98.9	56.8	......	......	.....	21.39

* Polarization +1.8. † Polarization +1.58.

Sterols.—Small quantities of two neutral substances, $C_{31}H_{58}O_2$ and $C_{29}H_{45}O_2$, isolated by Neville,[2] probably belong with the phytosterols or a related group. The sterols isolated by Pavlas[3] were closely related isomers with the formula $C_{28}H_{46}O_2$, about half of which were conjugated.

Acids.—The acidity of beet juice has been accounted for by Von Lippmann and others as due to the presence of various organic acids including *citric*, *malic*, *tartaric*, *oxalic*, *malonic*, *succinic*, and others. In view of the difficulties attending the separation of these acids, as shown by more recent work, further investigation seems desirable. According to Smolenski,[4] the precipitate that settles on warming beet juice, after removal of alcohol-, water-, and hydrochloric acid-soluble substances and drying, yields, on extraction with alcohol, a substance with the formula $C_{28}H_{44}O_8$ (melting point 214 to 216° C.; $[\alpha]_D$ in alcohol +21 to 24.9°). By hydrolysis the *resin acid* $C_{22}H_{36}O_2$ of Andrlik[5] and *glucuronic acid* were obtained. Viehoever, Kunke, and Mastin[6] found 0.17 per cent and Arbenz[7] 0.03 per cent of oxalic acid.

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[1] Z. physiol. Chem. 1926, **159**, 120.

[2] J. Chem. Soc. 1912, **101**, 1101.

[3] Listy Cukrovar. 1929, **47**, 527.

[4] Z. physiol. Chem. 1911, **71**, 266.

[5] Chem. Zentr. 1898, I, 621.

[6] Science 1917, **46**, 546.

[7] Mitt. Lebensm. Hyg. 1917, **8**, 98.

Carbohydrates.—Although *sucrose* is the predominating sugar of the beet, *dextrose* and *levulose* are also present in appreciable but variable amounts and *raffinose* occurs in small amount.

H. Colin,[1] corroborating Girard,[2] found that the leaves always contain *sucrose*, *dextrose*, and *levulose*. In the margins of the leaves the amount of levulose exceeds that of dextrose; in the petioles, especially near the base, dextrose predominates. Sucrose is formed in the leaf during the daytime but is inverted by sucrase in the margins at night. The sucrose of the root is condensed from the dextrose and levulose in the crown (neck) of the root. Invertase is not normally present in the root but when under certain conditions the sucrose migrates to the leaves it is inverted, the ratio of sucrose to reducing sugar regularly decreasing from the root upward.

In a review of the literature, H. Colin[3] notes that authorities are not agreed as to whether *sucrose* is synthesized in the leaf and translocated to the root or is polymerized in the root from invert sugar formed in the leaves.

Loisseau[4] was the first to find *raffinose* in sugar-beet molasses. Tollens[5] showed that it is identical with the melitose found by Johnston[6] in eucalyptus manna and the gossipose found by Ritthausen[7] in cottonseed meal. Von Lippmann[8] isolated raffinose from beet juice, thus refuting the claim of some chemists that it is produced solely during manufacture. Ordinarily the amount is small but under certain conditions it is considerably increased. Its synthesis appears to be due to enzymes and is connected with changes of pectin and other galactan substances in the presence of sucrose. According to Browne,[9] only 0.01 to 0.02 per cent is commonly present in the sugar beet, although under certain conditions not well understood it may occur in much larger amounts. Pellet[10] by improved methods reports 0.8 to 1.5 per cent in beet molasses, corresponding to 0.03 to 0.06 per cent in the beets.

Pectins.—Ehrlich and Sommerfeld[11] extracted finely ground beets with water at 55 to 60° C. to remove the sugars, then boiled several times for several hours with water thus obtaining *hydropectin*, representing 25 to 30 per cent of the dry matter. A higher yield, up to 50 per cent, was secured by boiling under one to two atmospheres' pressure. The hydropectin was separated in the form of yellow or brown plates. On treatment with warm 70 per cent alcohol, araban was removed, leaving a residue of calcium and magnesium salts of *pectinic acid*. This acid, from data secured, was regarded as consisting of 3 acetyl, 1 arabinose, 1 galactose, 2 methyl, and 4 galacturonic acid groups. This corresponds to the formula $C_{43}H_{62}O_{37}$ and the molecular weight 1170 which agrees with the elementary analysis. The molecular weight 1380, determined on solutions, corresponds to the decahydrate. The pectin of the sugar beet accordingly appears to be triacetyl-arabino-galacto-dimethoxy-tetragalacturonic acid.

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[1] Rev. gén. botan. 1916, **28**, 289, 321, 368; 1917, **29**, 21, 56, 89, 113.

[2] Compt. rend. 1883, **97**, 1305; 1884, **99**, 808.

[3] Bull. ass. chim. dist. 1917, **35**, 171.

[4] J. fabr. sucre 1876, **24**, 52; 1878, **26**, 22.

[5] Ber. 1885, **18**, 26.

[6] J. prakt. Chem. 1843, **29**, 485.

[7] Ibid. **29**, 351.

[8] Ber. 1885, **18**, 3087.

[9] Handbook Sugar Anal., New York, 1912, p. 733.

[10] Bul. ass. sucr. dist. 1917, **35**, 106.

[11] Biochem. Z. 1926, **168**, 263.

See also Introduction, Apple, and Orange.

Phosphorus-Organic Compounds. *Lecithin.*—A water-soluble phosphatide was isolated by Grafe and Horvat[1] from the sugar beet as the lead salt. It yielded on hydrolysis oleic, palmitic, and glycerophosphoric acids, choline, and glutaric acid, but no carbohydrate could be detected. Another phosphatide contained a reducing substance believed to be a carbohydrate.

Phytin.—Bagaoisan[2] found in dry sugar beets about 10.55 per cent.

Colors.—Red beets, according to Schudel,[3] owe their color to *betanin*, an anthocyanin, having the following composition: C 55.16, H 4.96, and N 8.57. Its anthocyanidin or sugar-free derivative *betanidin*, being unstable, was obtained only as ethylated betanidin which is violet-red.

The chromogen of sugar beets, according to Kozlowski,[4] is yellowish and amorphous; that of the wild beet (*B. maritima* L. = *B. vulgaris* L.) is white, crystallizing in tablets. Both have the properties of saponins. By oxidation they yield colors passing from yellow through red to violet, hence the author believes that the color of the beet is due to oxidation and not reduction.

Formaldehyde.—Gentil,[5] by distillation, obtained from beet root 3 to 5 and from beet leaves 5 mg. per kilo. Whether this exists ready formed in the beet does not appear.

Mineral Constituents.—The analyses below, made at the Massachusetts Station, are from Haskins' Compilation[6] recalculated to percentages in the ash. The respective percentages of ash in the roots were 11.3, 10.4, and 12.2.

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[1] Biochem. Z. 1925, **159**, 449.

[2] Philippine Agr. 1932, **21**, 53.

[3] Inaug. Dis. Tech. Hochs. Zürich, 1918.

[4] Compt. rend. 1921, **173**, 855.

[5] Bul. ass. chim. sucr. dist. 1909, **27**, 169.

[6] Mass. Agr. Exp. Sta. 1919, Spec. Bul. p. 90.

Composition of Beet Ash (Haskins)

	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3
	%	%	%	%	%	%
Red beet.........	39.0	7.9	4.4	2.7	8.0	...
Sugar beet........	46.2	7.7	5.7	3.8	9.6	1.0
Mangels..........	31.1	10.7	4.9	3.3	7.4	...

Colin and Billon[1] state that the average ash content of French beets is much lower than formerly and the potash in the ash has dropped from approximately 50 to 25 per cent.

Relation of Ash and Ash Content to Sucrose and Nitrogen.—According to Andrlik and Urban,[2] the content of pure ash and nitrogen increases as the sugar content decreases, the averages for a normal year being 0.464, 0.172, and 18.4 per cent respectively. In 3 representative samples they report sucrose 19.10, 17.66, and 16.55 per cent, and in the ash potash (K_2O) 42.38, 38.96, and 37.61 per cent and soda (Na_2O) 7.32, 12.95, and 16.68 per cent respectively, showing that high potash but low soda are correlated with high sucrose content.

Minor Mineral Constituents. *Iron.*—Garden beet, 4 samples, 152 to 240, aver. **141** mg. per kilo, dry basis (Remington and Shiver).[3] Garden beet, 2 samples, 23.6 mg. per kilo, fresh basis (Peterson and Elvehjem).[4]

Aluminum.—Beet 4.8 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[5] Mangold 6 mg. per kilo, dry basis (Bertrand and Lévy).[6]

Manganese.—Garden beet, 6 samples, 33.1 to 85.1, aver. **55.4** mg. per kilo, dry basis (Remington and Shiver).[3]

Copper.—Garden beet, fresh basis 3.2, dry basis 24.5 mg. per kilo (Guérithault).[7] Root, 6 samples, 5.6 to 12.3, aver. **9.1** mg. per kilo, dry basis (Remington and Shiver).[3] Beet, 2 samples, 1.9 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[8]

Zinc.—Red beet 9.3, fodder beet 3.3 mg. per kilo, fresh basis (Bertrand and Benzon).[9] Beet 17.8 to 38.7 mg. per kilo, dry basis (Hubbell and Mendel).[10]

Iodine.—Present (Winterstein).[11]

[1] Compt. rend. 1931, **192**, 1746.

[2] Z. Zuckerind. Böhmen 1909, **33**, 418, 477.

[3] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] Am. J. Physiol. 1929, **90**, 72.

[6] Bul. soc. hyg. aliment. 1931, **19**, 359.

[7] Compt. rend. 1920, **171**, 196.

[8] J. Biol. Chem. 1929, **82**, 465.

[9] Bul. soc. hyg. aliment. 1928, **16**, 457.

[10] J. Biol. Chem. 1927, **75**, 567.

[11] Z. physiol. Chem. 1918, **104**, 54.

ROOTS OF THE MUSTARD FAMILY

(*Cruciferæ*)

Roots of species of *Brassica*, notably the rutabaga, the turnip, and certain Chinese species, are known under the general name of turnips. Radishes in the Occident are grown chiefly as relishes, although the large oriental forms are suitable for cooking, closely resembling turnips in flavor. Horse-radish, a perennial, has an intensely pungent root used only as a condiment.

COMPARATIVE MACROSCOPIC STRUCTURE.—Garden varieties of rutabagas, turnips, and radishes differ greatly in form and color. Forms with colorless skin and flesh occur in all three groups. A bright red skin is common in radishes. Yellow flesh is characteristic of many varieties of rutabagas and of some varieties of turnips.

Because of the nearness of the cambium to the surface, in paring rutabagas and turnips, practically all outside of that layer is removed.

COMPARATIVE MICROSCOPIC STRUCTURE. — *Volatile mustard oil,* to which the radish and horse-radish owe their tang and the turnip and rutabaga their flavor, is lacking in microscopic characters.

Transitory starch may occur in small amount in the radish, rutabaga, and turnip during growth, but starch is usually absent or present in very small amount in the mature root. *Reserve starch,* however, is present in all parts of the horse-radish root throughout the growing season and if left in the ground is still present when the ground thaws in the Spring, although in storage some of it under certain conditions seems to disappear.

Yellow *chromatophores* occur in yellow rutabagas and turnips. *Soluble coloring matter* occurs in the skin of red radishes and of purple or red top rutabagas and turnips.

Stone cells, often much elongated, are present in the hypoderm and cortex of the horse-radish.

The *vessels* vary greatly even in the same species. Pitted, scalariform, and variously reticulated forms are present throughout the xylem, but forms characteristic of the group, much less of the species, are lacking, although the vessels of the horse-radish are larger (up to 140 μ) and with relatively shorter joints than those of the rutabaga, turnip, and radish. *Cobweb tissues,* consisting of abortive vessels and surrounding parenchyma, are present in all the biennial roots examined. Spiral vessels are largely confined to the crown which is morphologically a stem.

COMPARATIVE CHEMICAL COMPOSITION.—*Sucrose* and *reducing sugar* in various proportions constitute the bulk of the solid matter of turnips and rutabagas. *Starch* appears to be the chief constituent of horse-radish, but figures are not available.

RADISH

Raphanus sativus L.

Fr. Radis. Sp. Rábano. It. Ravanello. Ger. Radieschen.

Whether the cultivated radish was derived from the wild, slender-rooted radish of Europe (*R. Raphanistrum* L.), or from another species native of the Far East where the radish has been cultivated in numerous varieties for many centuries, has been the subject of much controversy. Carrière thought he had proved the former theory when by growing the wild radish in rich soil he developed a form with a fleshy root, but this merely showed how fleshy roots are obtained from the narrow form. The presence of joints and partitions of the pod (silique) in the wild radish and the absence of these in the cultivated form also do not denote a difference in species since plants with one form of pod may be derived from those with the other.

MACROSCOPIC STRUCTURE.—The shapes vary from short and globular, abruptly narrowing to a slender terminal, to long and tapering. While our Summer varieties, eaten raw, are small, preferably only about 2 cm. in diameter, in the Orient there are varieties yielding roots reaching 35 to 60 cm. in diameter, which are eaten cooked as well as raw. The color of the thin rind varies from pure white to black, the popular color being bright red. In all, the flesh is white or pink.

A globular radish 2.5 cm. in diameter, cut through the broadest part, presents the appearance shown in Fig. 13. The dark radiating lines are the bundle rays, increasing in number toward the periphery; the white portions between the bundle rays are medullary rays and accompanying parenchyma. The outer white portion consists of cortex and phloem. Compared with umbelliferous and composite roots, the narrow phloem zone and the nearness of the cambium zone to the surface are noteworthy.

MICROSCOPIC STRUCTURE (Figs. 14 and 15). **Cork** (Fig. 14, *S*; Fig. 15, *su*).—Only two or three rows of cells are present. The cells as seen in tangential section are longitudinally elongated.

Cortex (Fig. 14, *C*).—The cells in cross section are distinguished from those of the cork by their larger size and isodiametric form.

Phloem (*P*).—There is little differentiation of the cells of the ground parenchyma of the bundle rays and of the medullary rays. Only in small roots or in the tail of large roots is the arrangement of cells in radial rows, a characteristic of horse-radish, noteworthy. The *sieve tubes* (*s*) are distinguished from the ground parenchyma by their smaller size, the peculiar refraction of the somewhat thickened walls, and the arrangement in small groups. The contraction of the phloem rays at the outer ends is marked in this root as in the turnip and rutabaga.

Cambium (*Cm*).—The cells in the bundle rays are not so broad as those in the medullary rays.

Xylem (X^1 to X^7).—Starting with the diarch central group (X^1), the *vessels* form groups occurring at intervals in the ground parenchyma up to the cambium zone. Undeveloped vessels are often surrounded by

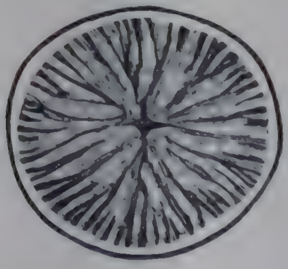

Fig. 13.

Fig. 13.—Radish. Root in cross section. × 1. (A.L.W.)

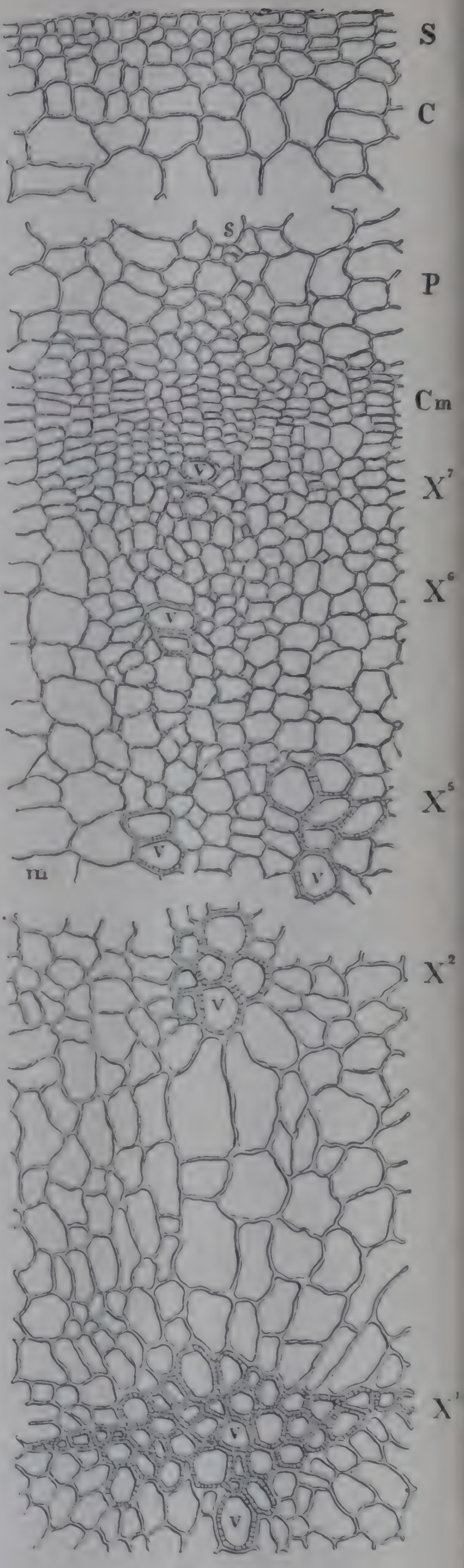

Fig. 14.

Fig. 14.—Radish. Root in cross section, magnified. *S* cork; *C* cortex; *P* phloem with *s* sieve tubes; X^1 primary xylem; X^2, X^5, X^6, and X^7 xylem zones; *v* vessels; *m* medullary ray. × 160. (A.L.W.)

radiating parenchyma forming a cobweb-like tissue. The vessels (Fig. 15) seldom reach 50 μ; even in the center of good-sized roots most of them are much smaller. While they are generally reticulated or reticulated-pitted (*r*) in the center, narrow spiral (*sp*) forms are not unusual on the edges of main groups. Large spiral vessels are numerous in the crown. The joints range from short to long (over 100 μ). *Fibers* (*bf*) with thin walls are evident in good-sized roots. The *parenchyma cells* about the central vessels and in the medullary rays have swollen walls, but a sharp differentiation of medullary and xylem parenchyma is not usually evident except in small roots.

Chief Structural Characters.—Root globular or elongated; rind white, red, or black; flesh white or pink.

Cork cells longitudinally elongated. Cortex cells isodiametric, characterless. Parenchyma of phloem and medullary rays not sharply distinguished; sieve tubes in cross section distinguished by smaller size and refraction. Xylem rays with groups of vessels and cobweb-like groups; vessels in root proper mostly reticulated or reticulated-pitted, less often spiral, up to 50 μ.

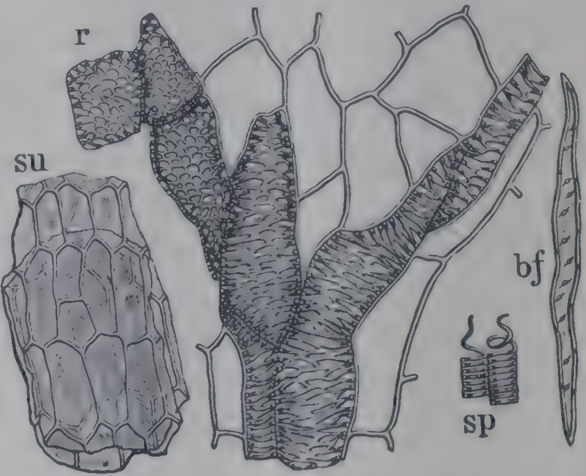

Fig. 15.—Radish. Elements of root in surface view. *su* cork layer; *r* reticulated vessels; *sp* spiral vessels; *bf* bast fiber. × 160. (A.L.W.)

CHEMICAL COMPOSITION.—Dahlen[1] gives a single analysis each of the Spring and Fall crop of *R. sativus radicula* DC.; Atwater and Bryant[2] give results on the edible portion (70 per cent) of 4 samples of the common radish; and Chung and Ripperton[3] give 2 analyses of the oriental radish (*R. sativus longipinnatus*), one being of the short oblong variety preferred by the Chinese and known as *Loh-bak choi*, the other of the large long form grown by the Japanese known as *Daikon.*

Agcaoili[4] reports 0.82 per cent of protein in the Chinese radish grown in the Philippines.

Carbohydrates.—Wittmann[5] found in the common radish 0.57 and in the black radish 0.88 per cent of *pentosans.*

The white precipitate, obtained by Takahashi[6] on concentrating

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[1] Landw. Jahrb. 1875, **4**, 613.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[4] Philippine J. Sci. 1916, **11**, 91.

[5] Z. landw. Versuchsw. 1901, **4**, 131.

[6] J. Agr. Chem Soc. Japan 1932, **8**, 393.

Composition of Radish

	Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
	%	%	%	%	%	%	%
Dahlen:							
May	94.31	1.15	0.10	3.10	1.14	0.65	0.69
October	93.47	1.45	0.11	3.31	0.52	0.73	0.93
A. and B.:							
Min	86.6	0.5	0.0	3.4*	....	0.7	0.7
Max	94.8	3.0	0.3	8.3*	....	0.7	1.8
Aver	**91.8**	**1.3**	**0.1**	**5.8***	....	**0.7†**	**1.0**
C. and R.:							
Chinese	95.04	1.08	0.03	2.39	....	0.65	0.81
Japanese	94.85	0.87	0.03	3.03	....	0.64	0.58

* Includes fiber. † 2 samples.

the expressed juice of oriental radishes (var. *macropodus*) and addition of alcohol, on extraction with water yielded a yellow-brown gelatinous precipitate believed to be hydrated *pectin*, which on further purification contained over 78 per cent of galacturonic acid. Free pectic acid was obtained by treatment with hydrochloric acid.

Phosphorus-Organic Compounds. *Phytin.*—In the root, Bagaoisan[1] found 2.53 per cent, dry basis.

Colors.—Anthocyanins of radishes differ with the variety. Schudel[2] found in a yellow-red variety *raphanin*, the anthocyanidin of which is pelargonidin, and in a red variety *rubin*, the anthocyanidin of which is cyanidin.

Mineral Constituents.—Chung and Ripperton[3] found in the Chinese and Japanese varieties respectively: calcium 0.021 and 0.023, iron 0.0006 and 0.0005, and phosphorus 0.026 and 0.019 per cent; also alkalinity of the ash 9.60 and 4.50 expressed as cubic centimeters of normal acid per 100 grams of fresh vegetable.

Minor Mineral Constituents. *Iron.*—Radish, 2 samples, 13.6 mg. per kilo, fresh basis (Peterson and Elvehjem).[4]

Aluminum.—Rose radish harvested in March 210, in April 440 mg. per kilo, dry basis (Bertrand and Lévy).[5]

Manganese.—Radish 16.66 mg. per kilo, dry basis (Quartaroli).[6] Radish 13.7 mg. per kilo, dry basis (Peterson and Skinner).[7]

Copper.—Radish 3.8 fresh, 52.7 mg. per kilo, dry basis (Guérithault).[8] Radish

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[1] Philippine Agr. 1932, **21**, 53.

[2] Inaug. Dis. Zürich, 1918.

[3] Loc. cit.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] Compt. rend. 1931, **192**, 525.

[6] Ann. chim. appl. 1928, **18**, 47.

[7] J. Nutrition 1931, **4**, 419.

[8] Compt. rend. 1920, **171**, 196.

19.8 mg. per kilo, dry basis (Quartaroli).[1] Radish 1.6 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[2]

Zinc.—Pink radish 1.6 mg. per kilo, fresh basis (Bertrand and Benzon).[3]

RUTABAGA

Brassica campestris L. var. *Napo-Brassica* DC. = *B. oleracea* L. var. *Napo-Brassica* L. = *B. Napus Napobrassica* Rchb.

Fr. Chou-navet. It. Rapa svedese. Ger. Rutabaga.

In England, roots of this species are known as swedes or Swedish turnips, in the United States as rutabagas. The common type is orange-yellow, hence many people use the terms rutabaga and yellow turnip as synonymous. There are, however, white varieties of the rutabaga, and yellow varieties of the common or Summer turnip. A better, although not infallible, distinction is the form, the rutabaga being top-shaped with a neck-like crown or stem, while the common turnip is commonly flattened, abruptly narrowing to the taproot, with a depression at the top bearing the leaves.

The full-grown leaves of the rutabaga are smooth and glaucous; those of the turnip are more or less hairy. Both vegetables are biennials. The flowers of the rutabaga are cream-colored and of considerable size, while those of the turnip are bright yellow and small.

Fleshy roots are also produced by a variety of *B. chinensis* L. described by Bailey.[4]

MACROSCOPIC STRUCTURE.—The specimen selected for study was somewhat elongated, tapering gradually to the narrow taproot, with a purple top and orange flesh. The diameter measured about 10 cm., the distance from the periphery to the cambium layer 2 to 3 mm. Roots twice that size are not uncommon. On paring, little, if any, of the cortex remained. Exclusive of the crown or short stem marked by leaf scars, the upper half was smooth, while the lower half was roughened by transverse wrinkles from which sprang rootless and sometimes secondary roots. Some varieties also have a few rootlets in the upper half.

The cortex and outer phloem zone were a uniform light orange color; the inner ends of the phloem rays, the cambium layer, and the groups of vessels and surrounding cells were deep orange. The bundle rays were particularly marked near the cambium layer where the vessel groups of each ray were close together; further inward the radial arrangement was less noticeable. The vessel groups also were arranged more or less distinctly in concentric circles. On casual examination, only the numerous deep orange rays near the cambium layer and the uniform inner tissue, spotted here and there with large deep orange vessel groups, were noticeable.

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[1] Ann. chim. appl. 1928, **18**, 47.

[2] J. Biol. Chem. 1929, **82**, 465.

[3] Bul. soc. hyg. aliment. 1928, **16**, 457.

[4] Cornell Agr. Exp. Sta. 1894, Bul. 67.

MICROSCOPIC STRUCTURE.—The general structure resembles that of the radish (see Fig. 14), but the vessels usually reach a larger size.

Cork (Fig. 16, *su*).—Most of the cells in surface view are approximately rectangular and longitudinally elongated; some, however, are polygonal, isodiametric, or elongated in various directions.

Cortex.—The cells are isodiametric and characterless.

Phloem.—There is no sharp demarcation or difference in cell form between the cortex and outer phloem, or between the phloem parenchyma and the medullary rays. In longitudinal radial section there is little indication of longitudinal elongation or arrangement side by side in radial rows, a striking feature of horse-radish as well as of umbelliferous and composite roots. *Sieve tubes* in cross section are recognized by their smaller size and highly refractive walls. *Chromatophores*, such as are mentioned below, are present in the inner end of the phloem rays of this as well as of other yellow varieties.

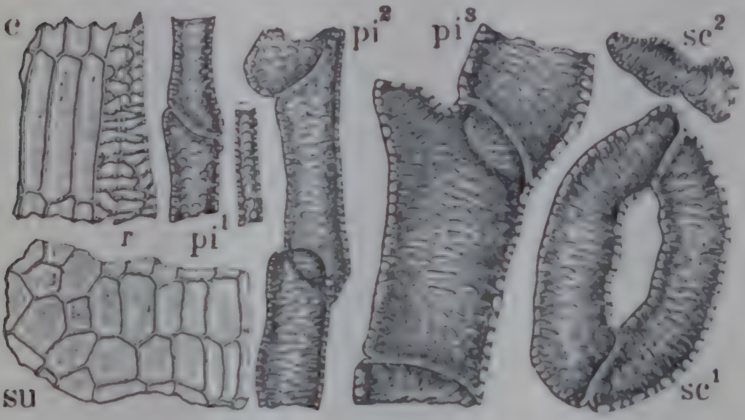

Fig. 16.—Rutabaga. Elements of root. *su* cork in surface view. The following in longitudinal section: *c* cambium cells; *r* vessels in the formative stage with delicate reticulations; pi^1 vessels with round or broadly oval pits; pi^2 and pi^3 vessels with elongated pits; sc^1, sc^2 sclerenchyma cells or modified vessels. × 160. (A.L.W.)

Cambium (Fig. 16, *c*).—Longitudinal elongation of the cells and arrangement side by side in radial rows are here marked. Chromatophores are present.

Xylem.—Owing chiefly to the rapid growth and abnormal development, the arrangement of cells and vessels shows much distortion.

The *vessels* are largely pitted, or pitted-reticulated, varying up to 75 μ in breadth, with joints much longer (often up to 200 to 300 μ) than in horse-radish. Adjoining the cambium layer the narrow undeveloped vessels have delicate spiral or reticulated markings (Fig. 16, *r*). Some of the narrower vessels (pi^1) have nearly round pits; most of the broader vessels (pi^2, pi^3) have transversely or diagonally elongated pits. Robust spiral vessels are confined chiefly to the crown.

Sclerenchyma cells of various types also occur among the vessels of which they are modifications. Two of these sometimes coalesce at the ends to form collar-like bodies (*sc*¹). Others are short (*sc*²), radically different from true vessels.

Cobweb tissues.—Contributing further to the irregularity of the structure are striking groups of small cells (Fig. 17, *w*) concentrically arranged about abortive vessels and showing evidence of cell division.

The *medullary rays* are often indistinguishable from the adjoining parenchyma, and arrangement in radial rows is often indistinct.

CHIEF STRUCTURAL CHARACTERS.—Root top-shaped with a neck; flesh yellow or white.

Cork cells in surface view polygonal, isodiametric, or elongated. Parenchyma cells of cortex, phloem, and xylem mostly isodiametric, not in distinct radial rows as seen in longitudinal section. Vessels up to 75 μ broad, mostly pitted or pitted-reticulated, joints up to 300 μ long. Cobweb-like groups common. Yellow turnips with chromatophores.

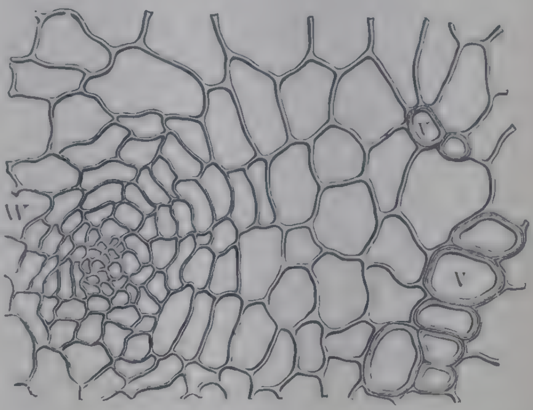

FIG. 17.—Rutabaga. Cross section through groups of mature vessels *v* and cobweb-like tissue *w* consisting of thin-walled parenchyma cells arranged concentrically about a group of abortive vessels. × 160. (A.L.W.)

CHEMICAL COMPOSITION.—Rutabagas in certain regions are known as turnips and are sometimes so classified even in reports of analysts. For this reason, as well as because they have practically the same composition as turnips, analyses of both roots are here considered together.

The averages of 3 analyses of rutabagas and of 6 analyses of turnips, both with the same water content, given in Lindsey, Smith, and Beals' Compilation,[1] show the similarity in composition:

COMPOSITION OF RUTABAGAS AND TURNIPS (LINDSEY ET AL.)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Rutabagas.....	3	89.0	1.2	0.2	7.2	1.3	1.1
Turnips.......	6	89.0	1.5	0.2	7.0	1.3	1.0

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[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul., p. 13.

In these analyses the average protein content of the turnips is higher than that of the rutabagas, whereas in numerous analyses compiled by König (who includes some rutabagas with turnips) the reverse is true; in both cases, however, the difference is slight.

For several years Werenskiold analyzed roots submitted by Norwegian agricultural societies, the results for the year 1893[1] being of special interest because of the wide range in percentages of sucrose and of dextrose and in the relative amount of these sugars.

Composition of Rutabagas and Turnips (Werenskiold)

(Results on dry basis)

	Samples	Water	Protein	Fat	N-f. ext.	Dextrose	Sucrose	Fiber	Ash
		%	%	%	%	%	%	%	%
Rutabagas	15								
Min.		85.88	6.19	0.35	69.34	4.22	8.07	9.92	6.10
Max.		89.78	13.80	1.42	74.22	57.93	44.40	13.36	8.85
Yellow turnips	37								
Min.		86.80	6.58	0.28	56.04	28.10	1.29	11.16	6.74
Max.		93.05	15.56	2.79	72.34	52.82	16.58	16.13	12.37
White turnips.	8								
Min.		89.76	6.68	0.28	....	34.15	4.12	....	7.01
Max.		92.22	15.90	0.87	63.10	52.31	15.55	15.73	9.86

The maximum dextrose and the minimum sucrose in the yellow and white turnips were on the same sample. Amide nitrogen in percentages of the total nitrogen ranged as follows: rutabagas 43.0 to 66.7, yellow turnips 43.0 to 61.3, and white turnips 53.9 to 61.8.

Influence of Season and Variety.—Shutt[2] reports the results of analyses of rutabagas grown in Canada. Considering the averages for each year from 1905 to 1910, the solids, calculated to the root, ranged from 9.87 to 12.18, and the sucrose, calculated to the juice, from 1.07 to 1.78 per cent. The maximum content of solids and sucrose occurred in the same year, but the percentage of sucrose corresponding to the minimum percentage of solids was 1.52, which was not the minimum but next to the maximum. A comparison of the results on 10 varieties grown during two successive years, although showing on the average markedly less solids and sucrose in the second year than in the first, does not show this difference in the case of some varieties. For example, Magnum Bonum contained respectively in the two years solids 10.67 and 10.51 and sucrose 1.18 and 0.51 per cent, but Perfection Swedes contained solids 11.05 and 11.82 and sucrose 1.37 and 1.42 per cent.

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[1] Chem. Control Sta. Christiania, Rep. 1893, p. 11.

[2] Can. Dept. Agr., Rep. Dom. Chem. 1910, p. 210; 1911, p. 178.

Incidental to the study of the finger and toe disease of rutabagas (swedes), Whitehead[1] analyzed 4 varieties with results as follows:

Composition of Varieties of Rutabagas (Whitehead)

	Solids	Sugars in roots	Reducing sugars in juice	Sucrose in juice
	%	%	%	%
Magnum Bonum.........	8.8	5.47	5.35	0.31
Danish..................	10.6	5.86	5.80	0.29
Danish..................	11.1	6.25	6.20	0.29
Yellow turnip............	8.5	3.32	3.30	0.15

Influence of Locality.—Rutabagas (swedes) grown in different localities from the same lot of seed were shown by Lauder[2] to vary as follows: total solids 10.32 to 12.66, soluble solids 7.83 to 9.48, insoluble solids 2.49 to 3.17, and sugars 6.41 to 7.33 per cent. Total solids were found to be the best index of quality.

Influence of Fertilizers.—Results secured in fertilizer experiments by Hendrick[3] show that the stunted turnips grown without manure are high in protein (three times normal), fiber, and ash content but normal in sugar content. Given a supply of phosphoric acid, the percentage of nitrogen was not appreciably affected by nitrogenous fertilizers although the percentage of sugar was somewhat increased.

Proteins.—Williams[4] isolated the soluble protein of the rutabaga by heating the juice at 90° C. One preparation contained the following percentages: water 1.81, nitrogen 14.09, and ash 8.6. Hydrolysis and determination of the amino acids, employing Fischer's and Kossel and Kutscher's methods, yielded the results tabulated on the next page.

In rutabaga protein Fürth and Lieben[5] found tryptophane 3.3 per cent.

Nitrates.—Attention was called by H. and E. Schulze[6] to the nitric

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[1] Welsh J. Agr. 1925, **1**, 176.

[2] Scot. J. Agr. 1927, **10**, 428.

[3] Glasgow and W. Scotland Tech. Col., Agr. Dept. Rep. 1895, p. 23.

[4] J. Agr. Sci. 1917, **8**, 182.

[5] Biochem. Z. 1921, **122**, 58.

[6] Landw. Vers.-Stat. 1867, **9**, 242, 434.

PRODUCTS OF HYDROLYSIS OF RUTABAGA SOLUBLE PROTEIN (WILLIAMS)

	%
Humin bodies	4.74
Glycocoll	0.27
Alanine	3.58
Valine	9.95
Leucine Isoleucine	9.01
Cystine	+
Aspartic acid	6.98
Glutamic acid	3.18
Tyrosine	2.92
Phenylalanine	4.47
Proline	4.17
Tryptophane	+
Arginine	3.12
Lysine	4.35
Histidine	3.04
Ammonia	1.21
	60.99

nitrogen (saltpeter) present in rutabagas and turnips. In 6 varieties of turnips examined later by E. Schulze[1] the range in nitric nitrogen in the fresh roots was 0.004 to 0.051 and in the dry matter 0.058 to 0.65 per cent, corresponding to a range of total protein in the fresh roots of 0.64 to 1.20 and in the dry matter of 8.28 to 13.35 per cent.

Carbohydrates.—*Sucrose* and *Reducing Sugars.* See above tables.

Pentosans.—Sebelien[2] found in rutabagas 6.67 per cent of pentosans and 2.93 per cent of methylpentosans.

Mineral Constituents.—Determination of the mineral constituents in rutabagas and white turnips, reported in Haskins' Compilation,[3] gave the following results calculated to the fresh material:

	Water	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3
	%	%	%	%	%	%	%	%
Rutabaga	89.1	1.06	0.49	0.07	0.09	0.03	0.12	....
White turnip	89.5	1.01	0.39	0.08	0.09	0.03	0.10	0.10

Minor Mineral Constituents. *Iron.*—Turnip, peeled 6 mg. per kilo, fresh basis (Sherman).[4] Rutabaga 10.7, turnip 7.0 mg. per kilo, fresh basis (Peterson and Elvehjem).[1] Turnip, 2 samples, 4.2, 5.6 mg. per kilo, fresh basis (Toscani and Reznikoff).[2]

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[1] Landw. Vers.-Stat. 1872, **15**, 170.

[2] Chem. Ztg. 1906, **30**, 401.

[3] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul. p. 91.

[4] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

Aluminum.—Root, harvested in May 37 mg., in December 90 mg. per kilo, dry basis (Bertrand and Lévy).[3]

Manganese.—Turnip, 5 samples, 9.7 to 19.3, aver. **13.6**; leaves, 6 samples, 64.0 to 143.8, aver. **107.6** mg. per kilo, dry basis (Remington and Shiver).[4] Rutabaga 9.9, turnip 5.4 mg. per kilo, dry basis (Peterson and Skinner).[5]

Copper.—Turnip, 5 samples, 4.0 to 5.0, aver. **4.4**; leaves, 5 samples, 5.7 to 10.3, aver. **7.8** mg. per kilo, dry basis (Remington and Shiver).[4] Root 3.0 mg. per kilo, fresh basis (Guérithault).[6] Rutabaga 1.5, turnip 0.9 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

Zinc.—Turnip 0.8, rutabaga 3 mg. per kilo (Bertrand and Benzon).[8]

TURNIP

Brassica Rapa L. var. *rapifera* Metzg.

Fr. Navet. Sp. Nabo. It. Rapa. Ger. Weisse Rübe.

Distinctions from the rutabaga are described under that head.

MACROSCOPIC STRUCTURE.—Out of the bewildering variety of forms it is difficult to select one which may be regarded as the true type, especially as all have been developed from a slender-rooted form by breeding. For our purpose a white-fleshed, purple-top, flat form, about twice as broad as high, abruptly narrowing to the terminal, and without a neck, was selected as representing a type differing most from a yellow rutabaga.

Cross sections show a narrow rind separated by the cambium layer and that the leaves arise from a depression at the top.

MICROSCOPIC STRUCTURE.—No positive histological distinction from the rutabaga has been noted. In the specimens examined the vessels seem to have somewhat larger pores or pits than shown in Fig. 16 and may perhaps be more correctly designated as reticulated rather than porous or pitted, but similar large pores occur in white rutabagas and perhaps in some yellow varieties. Chromatophores are absent in the commonest forms as is also true of white rutabagas.

CHEMICAL COMPOSITION.—See Rutabaga.

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[1] J. Biol. Chem. 1928, **78**, 215.

[2] J. Nutrition 1934, **7**, 79.

[3] Compt. rend. 1931, **192**, 525.

[4] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[5] J. Nutrition 1931, **4**, 419.

[6] Bul. soc. hyg. aliment. 1927, **15**, 386.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

HORSE-RADISH

Radicula Armoracia Rob. = *Cochlearia Armoracia* L. = *Armoracia rusticana* Gaertn. = *Roripa Armoracia* Hitchc.

Fr. Raifort. It. Rafano. Ger. Meerrettig.

Unlike the common cruciferous vegetables, the horse-radish is a perennial and its root is eaten as a condiment rather than as a source of nutriment. From eastern Europe, its native home, it was carried westward, finally reaching the Western Hemisphere where it now often runs wild in wet places.

As the seeds seldom develop, the plant is propagated by root cuttings or sets, cataloged as " Maliner Kren," and in the home garden also by parts cut off from the edible root. It is most commonly dug late in the Autumn and stored for Winter use; it may also be dug in the early Spring. On the Continent the root is cut into ribbons and served with meat; in the United States it is commonly grated, mixed with vinegar, and served with raw oysters. The spicy flavor, resembling that of mustard, is due to volatile mustard oil.

MACROSCOPIC STRUCTURE.—The tough, whitish *main root* varies up to more than 3 cm. in diameter and up to more than 40 cm. in length according to the depth of the soil, branching at the end into a number of *secondary roots* which often reach great length. It is the latter which are cut into " sets "; they may also be grated with the main root. At the top of the main root and of about the same diameter is a short stem 1 cm. or so long with numerous transverse wrinkles or leaf scars. On the main root, as well as the root branches, there are occasional eyes with rootlets.

Macroscopic sections show no characters of special interest except that the cortex and phloem, relative to the xylem, are thicker than in radishes, rutabagas, and turnips.

MICROSCOPIC STRUCTURE (Fig. 18).—Compared with other edible roots of the family, the tissues are more woody and starch is abundant and persistent throughout the tissues. The intense pungency suggests the presence of myrosin cells or other specialized cells, especially in the cortex and phloem where the pungency is greater than in the xylem, which, if present, are lacking in distinctive characters.

Cork (*su*).—The older primary roots show in parts a layer of secondary cork which splits off from the primary cork. Longitudinal ridges of bark-like tissues consist of rounded suberized cells such as occur in lenticels.

Hypoderm (*h*).—Beneath the phellogen—the inner meristematic row of the cork layer—where there is no secondary formation and between the primary and secondary cork layers, are a few rows of larger and thicker-walled cells, often somewhat longitudinally elongated and porous, without intercellular spaces. Small *starch grains* occur in the outer cells, increasing in size inward. Isodiametric or moderately elongated *stone cells* (st^1) occur here and there.

Cortex (*cp*).—The *ground tissue cells* are thinner-walled than those of the hypoderm and for the most part are rounded with marked intercellular spaces. *Stone cells* occur singly or in groups, being here usually much elongated longitudinally (st^2). About the elongated stone cells the ground tissue cells are also elongated and without marked intercellular spaces. *Starch grains* are densely packed in the cells.

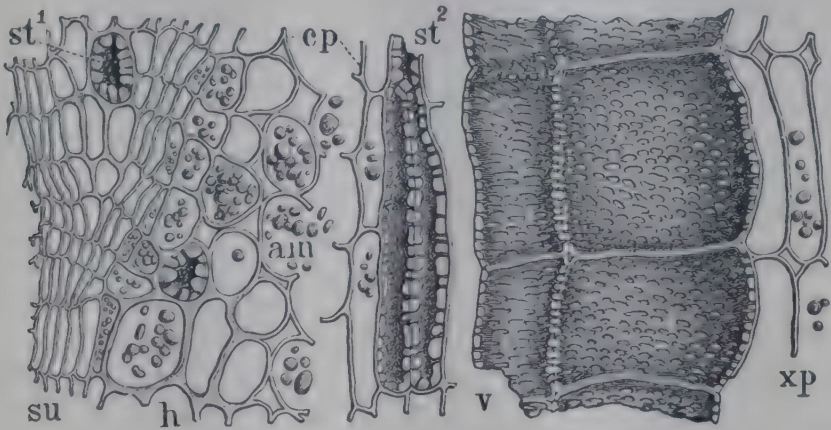

FIG. 18.—Horse-Radish. Root elements in longitudinal-radial section. *su* cork; st^1 stone cell in hypoderm cut off by secondary cork; *h* thick-walled hypoderm with stone cell; *cp* cortex parenchyma with *am* starch grains; st^2 elongated stone cells of cortex; *v* vessels of xylem; *xp* xylem parenchyma with cells (as in phloem parenchyma) side by side in radial rows. × 160. (A.L.W.)

They reach their full development in the outer layers, the maximum diameter being about 15 μ. They are spherical, ovoid, kidney-shaped, or irregular, and have an indistinct hilum. With polarized light they show dull crosses. They are particularly large in the neck (stem).

Phloem.—This zone consists of longitudinally elongated *parenchyma cells* in radial rows, and groups of characterless *sieve tubes* and *companion cells*, also *medullary rays*. The parenchyma with its narrow palisade-like cells is here, as in the xylem, distinctly different from the round-celled parenchyma of the cortex, but the starch is indistinguishable.

Cambium.—The longitudinally elongated cells differ from the phloem and xylem parenchyma in being narrower and thinner-walled.

Xylem.—The *parenchyma* (*xp*) does not differ appreciably from that of the phloem as to either the form of the cells or the starch. Small intercellular spaces occur at the angles. The *vessels* (*v*) are characterized by their great breath and short joints. In the latter respect they conform rather closely to the cells of the parenchyma, the joints being commonly 100 to 150 μ long and seldom over 200 μ. In breadth they reach 150 μ, many being broader than long and much broader than those of the turnip and rutabaga. *Cobweb-like tissues*, such as described and pictured as occurring in rutabaga (Fig. 17), are present also in this root.

CHIEF STRUCTURAL CHARACTERS.—Root whitish, with secondary roots at the lower end; neck wrinkled; cross sections white with cortex and phloem thicker than in radishes, rutabagas, and turnips.

Primary cork cells in transverse rows; secondary cork tissue present in parts. Hypoderm of thick-walled cells and short stone cells. Cortex of rounded, thin-walled cells with intercellular spaces passing into elongated cells about much elongated stone cells. Phloem and xylem parenchyma of longitudinally elongated cells side by side in radial rows. Vessels pitted, up to 150 μ broad, with joints usually less than 200 μ long (broader and shorter than in rutabaga and turnip). Starch grains up to 15 μ present throughout.

CHEMICAL COMPOSITION.—Dahlen[1] found the following:

COMPOSITION OF HORSE-RADISH (DAHLEN)

Water	Protein	Fat	N-f. ext.	Sugars, reducing	Fiber	Ash
%	%	%	%	%	%	%
73.85	3.35	0.31	18.30	trace	2.58	1.61

Results by Friese[2] on 5 samples are summarized below:

	Water	Solids	Acid No.*	Ash, total	Ash, alk.*	SO_3	SO_2	NaCl
	%	%	cc.	%	cc.	%	%	%
Whole:								
Min	57.02	21.43	4.52	1.30	6.05	0.33	0.010	0.013
Max	78.57	42.98	5.26	2.57	9.34	0.70	0.021	0.033
Aver	**72.07**	**27.93**	**4.82**	**2.11**	**7.93**	**0.45**	**0.015**	**0.026**
Outer †:								
Aver	**76.96**	**23.04**	**4.92**	**1.79**	**7.40**	**0.39**	**0.015**	**0.021**
Inner †:								
Aver	**73.05**	**26.95**	**5.11**	**2.09**	**9.14**	**0.39**	**0.019**	**0.025**

* Cc. normal alkali or acid per 100 grams sample. † 3 samples.

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[1] Landw. Jahrb. 1874, **3**, 613.

[2] Z. Unters. Nahr.-Genussm. 1925, **49**, 194.

Hematin.—Elliot and Keilin[1] obtained experimental proof that preparations of horse-radish root contain hematin as free acid hematin which does not combine with proteins below pH 9 and not completely until an alkalinity of over pH 10.5 is reached. The relation between peroxidase and hematin is not simple; at pH 10.5 the enzyme is nearly inactive.

Enzymes.—*Peroxidase* was first studied in the horse-radish root and the pumpkin by Bach.[2] It, together with *oxygenase*, as shown by Chodat and Bach,[3] make up what was once considered to be a single enzyme known as oxidase.

Mineral Constituents.—A summary of analyses by Friese[4] of the ash of the 5 samples referred to above follows:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Min...	29.44	8.84	7.49	2.13	0.08	0.14	0.08	5.56	23.59	6.40	0.78
Max..	31.62	16.17	11.52	3.25	0.10	0.29	0.10	9.51	29.86	10.55	0.90
Aver..	**30.34**	**11.66**	**9.27**	**2.67**	**0.09**	**0.21**	**0.09**	**7.54**	**27.09**	**9.37**	**0.84**

The analyses given by König show much less soda (Na_2O 3.96 per cent) and much more iron oxide (Fe_2O_3 1.94 per cent), also somewhat more phosphoric acid (P_2O_5 30.79 per cent) and silica (SiO_2 12.72 per cent), but results on other constituents are within the above limits.

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[1] Proc. Roy. Soc. (London) 1934, **B114**, 210.

[2] Ber. 1903, **36**, 600.

[3] Ibid. 1903, **36**, 606.

[4] Loc. cit.

ROOT-TUBERS OF THE PEA FAMILY

(*Leguminosæ*)

Of the four species yielding edible root-tubers here described, one, namely the tuberous vetchling, belongs in the *Vicia* tribe (*Viciex*), while the other three, namely the yam bean, the ground nut, and the kudzu, belong in the *Phaseolus* tribe (*Phaseolex*).

COMPARATIVE MACROSCOPIC STRUCTURE.—The tuberous roots of the tuberous vetchling and the ground nut are ovoid, of the yam bean turnip-shaped, of the kudzu sweet-potato-shaped. In the first three species, at least, they are formed in series on a slender connecting root axis.

COMPARATIVE MICROSCOPIC STRUCTURE.—Typical *cork cells*, several thick, form the protective covering, and *starch parenchyma*, *bast fibers*, and *crystal cells* (crystal fibers) occur in the cortex, phloem, and xylem of all four species.

The *starch grains* are truncated, of the tapioca type, in the tuberous vetchling (up to 20 μ), yam bean (up to 24 μ), and kudzu (up to 32 μ); in the ground nut they are mostly horned or gourd-shaped (up to 35 μ) with excentric hilum in the larger end.

Bast fibers in groups and accompanying *crystal fibers* with oxalate prisms are numerous in all but the ground nut, in which fibers occur sparingly.

Latex tubes are numerous in the ground nut but are not evident in the others, although kudzu contains tubes with deep brown contents which may be modified latex tubes.

In all the species the *vessels* are reticulated or pitted. They are largest in kudzu (up to 250 μ). In the ground nut they reach 130 μ but in the yam bean only 70 μ. Large spiral vessels, such as occur in the stem end of cruciferous, umbelliferous, and composite roots, are lacking since neither end is morphologically a stem.

COMPARATIVE CHEMICAL COMPOSITION.—The literature is limited to a few proximate and partial ash analyses. *Starch* is the chief constituent in all the roots described.

TUBEROUS VETCHLING

Lathyrus tuberosus L.

Fr. Gland de terre. Ger. Erdeichel.

Our knowledge of the history, composition, and structure of the root-tubers of this legume is based on the description of Hanausek.[1] The plant grows wild in central and southern Europe, and the tubers were used by the ancients for food. Before the introduction of the potato, which they resemble in composition, they were grown in Holland and central Germany.

Uncooked, the vegetable resembles green peas in flavor, and boiled suggests the chestnut. Like the ground nut, it is worthy of the attention of horticulturists and plant breeders.

MACROSCOPIC STRUCTURE.—The freshly gathered *root-tubers* are gray, red-brown, or black, elongated ovoid, reaching 7 cm. or more in length and 3 cm. or more in width. They resemble a potato in texture. On drying they become horny.

MICROSCOPIC STRUCTURE.—The **Cork** consists of several rows of typical cork cells, renewed by a two-rowed phellogen layer.

Cortex.—The *parenchyma cells* are rounded-polygonal and contain small starch grains and protein masses. The *starch grains* are of the tapioca type, the larger grains reaching 20 μ in diameter. They occur frequently in twins and triplets, less often in larger aggregates, and have the characteristic truncations of starches of the tapioca group. *Bast fibers* and *crystal fibers* with monoclinic oxalate crystals are striking elements.

Xylem.—The *vessels* are either pitted or reticulated, and the adjoining *wood parenchyma* has somewhat thickened, pitted walls. *Starch parenchyma* and groups of vessels form the major portion of the xylem; *bast fibers* and *crystal fibers* are also present.

CHIEF STRUCTURAL CHARACTERS.—Root-tubers small, elongated ovoid, of the consistency of potatoes.

Cork of usual type. Cortex of starch parenchyma, bast fibers, and crystal fibers; starch grains of the tapioca type, up to more than 20 μ, often in small aggregates. Xylem with reticulated and pitted vessels and pitted wood parenchyma; other xylem tissues as in cortex.

CHEMICAL COMPOSITION. Carbohydrates.—The presence of *maltose* was demonstrated by Meunier,[2] who states that this is the fourth plant in which this sugar has been found.

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[1] Z. allg. oesterr. Apoth.-Ver. 1883, Nr. 21.

[2] Compt. rend. 1933, **197**, 98.

YAM BEAN

Pachyrhizus erosus (L.) Urban = *P. angulatus* Rich.

Chin. Sar-gott.

The root-tubers of the yam bean are used as food in the tropics of both hemispheres, particularly Central America and China. Blasdale[1] found roots imported from China on sale in the Chinese Quarters of San Francisco, and the writers secured material for study from New York "Chinatown." Probably the species is indigenous throughout the tropics, although some hold that it was introduced into the East from tropical America. *P. tuberosus* Spreng. (jicama), a native of tropical America, has larger tuberous roots.

The specimens examined by both Blasdale and ourselves did not boil tender, but Chung and Ripperton[2] state that, although the skin is tough, the flesh is sweet and pleasantly flavored and of the consistency of potatoes. Blasdale notes that the chief use of the vegetable is for the preparation of starch which is said to be of excellent quality.

MACROSCOPIC STRUCTURE.—Blasdale's illustration and Fig. 19 herewith show that this vegetable resembles a large, flat turnip, except that it abruptly narrows at both ends into the narrow root which, as in the ground nut, connects a series of the tuberous enlargements. There are a number of depressions parallel with the axis, and transverse lenticel-like markings occur all over the surface.

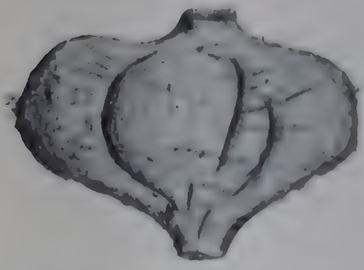

FIG. 19.—Yam Bean. Root. × ¼. (A.L.W.)

In cross section a dirty yellow ring is evident 3 to 10 mm. from the surface formed by cambium and xylem elements.

MICROSCOPIC STRUCTURE.—Literature is scanty on both the root and the starch, which latter is said to be made in China.

Cork.—The cork proper consists of several tiers of cells which in cross section are isodiametric or transversely elongated and in surface mounts are rounded-polygonal over the lenticel-like markings but elsewhere more nearly quadrilateral.

Cortex.—The *parenchyma cells* are for the most part isodiametric, each containing either starch grains or else a prismatic crystal or a cluster of such crystals, not combined, however, so as to form a typical rosette. The *starch grains* are of the tapioca type but are characterized by the great variation in size. For further description and illustration see Commercial Starches, Volume I. *Latex tubes* are not evident. Numerous *bast fibers*, usually less than 15 μ in breadth, with wide lumen, occur in groups in the inner cortex and outer phloem.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Hawaii Agr. Exp. Sta. 1929. Bul. 60.

Phloem.—Sieve tubes and companion cells form well-marked groups. Parenchyma cells of both bundle and medullary rays are in distinct radial rows.

Xylem.—Groups of *vessels* at the cambium layer form in cross section short rows; other groups occur at intervals. The vessels are reticulated or pitted, up to 70 μ broad. Groups of *bast fibers* are present throughout. *Starch* is abundant in the parenchyma of the xylem and broad medullary rays. *Crystal cells* are distributed through the tissues, often forming rows accompanying the bast fibers.

CHIEF STRUCTURAL CHARACTERS.—Root-tubers turnip-like, grooved at one end, narrowed at both ends to connecting cord; surface with transverse markings.

Cork cells, except on markings, nearly quadrilateral. Starch cells, crystal cells with prisms, and groups of bast fibers in both cortex and inner tissues; starch of tapioca type. Vessels up to 70 μ, reticulated or pitted.

CHEMICAL COMPOSITION.—Blasdale[1] gives a single analysis of the tuberous root of *P. erosus* (*P. angulatus*) sold in San Francisco, and he quotes analyses by Harrison and Jenman[2] of roots of *P. erosus*

COMPOSITION OF YAM BEAN ROOT

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sugars, non-reducing	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
P. erosus:									
H. and J.	85.70	1.04	0.51	10.67	1.38	....	2.03	0.71	1.37
Blasdale	78.09	2.18	0.18	17.32	1.84	3.71*	8.45	1.43	0.80
Agcaoili	84.47	0.82	0.12	8.93	....	....	......	0.28	0.38
Okumura	89.10	0.95	0.12	8.68	2.66	4.29	0.61	0.86	0.29
C. and R.	87.34	0.94	0.03	10.87	....	....	......	0.47	0.35
P. tuberosus:									
H. and J.	82.25	1.05	0.30	13.90	0.26	1.29*	8.46	0.66	1.84

*Sucrose.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Brit. Guiana Bot. Garden, Rep. Agr. Work 1891-2, p. 70.

and *P. tuberosus.* More recent analyses are by Agcaoili,[1] by Okumura,[2] and by Chung and Ripperton.[3]

Okumura isolated adenine, arginine, and choline.

Phosphorus-Organic Compounds. *Phytin.*—In the root, Bagaoisan[4] found 2.48 per cent, dry basis.

Mineral Constituents.—Okumura[5] reports an analysis of the ash, and Chung and Ripperton[6] give the following, on the basis of the fresh root: calcium 0.009, phosphorus 0.020, and iron 0.0019 per cent.

GROUND NUT

Apios tuberosa Moench = *Glycine Apios* L.

Fr. Glycine tubéreuse. Ger. Amerikanische Knollwicke.

Throughout the United States east of the Mississippi River the ground nut or wild bean, a climbing plant, grows wild in moist places and is cultivated to some extent for its fragrant chocolate-colored flowers which are borne in compact racemes. The tuberous roots are often described as tubers, but neither they nor the axis of which they are enlargements partake of the characters of modified stems. On cooking, they are mealy and good flavored.

In its native land, the ground nut is practically unknown as a food and American authors are strangely silent as to its nutritive value, but in central Europe it is grown as a substitute for potatoes and German authors give it due consideration as such.

A. fortunei Max., cultivated in Japan, also has edible roots.

MACROSCOPIC STRUCTURE.—When full grown the *tuberous roots* are cinnamon brown with transverse markings, reaching the size of small hen's eggs which they also resemble in shape. They are borne in series, the connecting root being slender and cord-like. On cutting, milky drops exude from all parts of the remarkably white flesh.

MICROSCOPIC STRUCTURE. Cork.—This is well developed, forming, as seen in cross section, about ten rows of cells. The color of the walls varies from brown at the surface to yellow and then at the phellogen layer to colorless.

Cortex.—Isodiametric *parenchyma cells* form the ground tissue.

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[1] Philippine J. Sci. 1916, **11**, 91.

[2] J. Tokyo Chem. Soc. 1920, **41**, 556.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[4] Philippine Agr. 1932, **21**, 53.

[5] Loc. cit.

[6] Loc. cit.

Most of these contain starch grains, but some here and there, occurring often in longitudinal rows, contain beautifully formed single monoclinic oxalate prisms. The *starch grains* are usually less than 35 μ in their longest diameter. In shape they vary greatly, the largest being often horned, beaked, or gourd-shaped with the hilum in the larger end. Occasionally they are united at the ends to form twins. Fissures, often crossing, may occur at the hilum, but there is no appearance of an "elongated hilum" such as is characteristic of leguminous seeds. With polarized light the dark lines cross sharply at the hilum. Narrow *bast fibers* with narrow lumen occur sparingly, either singly or in small groups, often adjoining the crystal cells. *Latex tubes* are conspicuous because of their breadth and the size of the latex grains, which reach 15 μ.

The **Phloem** contains starch but no bast fibers.

Xylem.—The *vessels* vary up to 130 μ in width and are intermediate in size between those of the yam bean and kudzu. They are either reticulated or spiral-reticulated, or else pitted, the pits being usually narrow and slit-like. *Starch cells*, *crystal cells* and *latex tubes*, such as occur in the cortex, are also present throughout the bundle tissues.

CHIEF STRUCTURAL CHARACTERS.—Tuberous root small, brown, ovoid, occurring at intervals along the slender root; flesh white.

Cork cells in about ten rows. Vessels reticulated, spiral-reticulated, and pitted, up to 130 μ wide. Starch cells, crystal cells with monoclinic prisms, and latex tubes throughout. Occasional bast fibers in cortex. Starch grains up to 35 μ, variously shaped with hilum in larger end.

CHEMICAL COMPOSITION.—Analyses of tuberous roots of the American species by Brighetti[1] and of the Japanese species by Hemmi[2] follow:

COMPOSITION OF GROUND NUT

	Water	Protein	Protein, pure	Fat	N-f. ext.	Starch	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Brighetti: *A. tuberosa*	70.69	4.06	1.88	1.00	18.65	7.02	2.60*	3.55	2.05
Hemmi: *A. fortunei*	68.60	4.19	1.56	0.19	24.52†	18.30	1.46	1.20	1.30

* Pentoses 5.54%. † Reducing sugars 1.15, non-reducing sugars 2.85, dextrin 0.99, and galactan 1.02%.

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[1] Staz. sper. agr. ital. 1900, **33**, 72.

[2] J. Col. Agr. Hokkaido Imp. Univ. 1918, **8**, 33.

The hemicellulose of the root-tuber of *A. tuberosa* yielded on hydrolysis *l*-arabinose and *d*-galactose.

MINERAL CONSTITUENTS.—Hemmi reports the following ash constituents in the sample of which an analysis is given above: potash 0.359, lime 0.543, phosphoric acid 0.116, and silica 0.319 per cent.

KUDZU

Pueraria hirsuta Schneider = *P. Thunbergiana* Benth.

Chin. Fan-kot. Jap. Kudzu.

Species of this genus, natives of the Far East, were formerly grouped under *Dolichos* or *Pachyrhizus.* The kudzu vine is much esteemed in China, Japan, and the southern part of the United States as an ornamental. In the Orient it is grown also for its thickened tuberous roots which are the source of an important starch, and for the stem that yields a textile fiber. The vegetable is sold in the Chinese Quarters of San Francisco and New York.

MACROSCOPIC STRUCTURE.—The root-tuber resembles an elongated sweet potato in form and size. On the surface are numerous, conspicuous, transversely elongated lenticel-like markings. The flesh is of a dirty yellow color. As is true of many root vegetables, the fleshy condition appears to be due in considerable degree to cultivation, roots of the plants used only for ornamentals being of moderate thickness and tougher than those developed for starch production.

MICROSCOPIC STRUCTURE.—The structure, which varies somewhat in specimens from different sources, resembles that of the yam bean.

Cork.—Typical cork cells, more or less quadrilateral in tangential section, form a protective coat several cells thick.

Cortex.—The *parenchyma* of nearly isodiametric cells contains starch grains of the tapioca type (see Commercial Starches, Volume I). The maximum size of the *starch grains* varies, the diameter reaching in some specimens about 16 μ, in others about twice that size. Scattered through the ground tissue are numerous bundles of *bast fibers* with thick walls and narrow lumen, often accompanied by longitudinal rows of crystal cells containing beautiful oxalate prisms, forming *crystal fibers.* *Tubes,* containing clear, rich brown contents, occur in the inner part especially adjoining the phloem rays. These may be modified latex tubes, less probably sieve tubes, as apparently the same kind of tubes occur in the xylem.

Phloem.—The fiber groups extend well into the phloem, dwarfing the sieve tubes. The parenchyma contains starch grains.

Xylem.—The *vessels* near the cambium ring reach a maximum of about 160 μ in diameter; further inward they are half again larger, measured through the longer diameter. They usually have numerous, small, somewhat elongated pits. Pitted *wood parenchyma* accompanies the vessels. *Fiber bundles*, accompanied by *crystal cells*, are also numerous. These bundles may adjoin vessel groups or occur isolated. The cells of the *xylem-* and *medullary-parenchyma* contain starch grains and are in more or less distinct radial rows as seen in longitudinal section.

CHIEF STRUCTURAL CHARACTERS.—Root-tuber fleshy, elongated, with transverse markings.

Cork typical. Cortex, phloem, and xylem with parenchyma containing starch grains of tapioca type up to 32 μ, also numerous groups of bast fibers accompanied by rows of cells containing oxalate prisms. Vessels up to 250 μ, mostly pitted. Occasional tubes with brown contents throughout.

CHEMICAL COMPOSITION.—An analysis of the peeled root tuber by Chung and Ripperton[1] follows:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
68.56	2.13	0.05	27.08	0.73	1.45

Mineral Constituents.—Chung and Ripperton[2] found in the peeled root tuber: calcium 0.066, phosphorus 0.069, and iron 0.0019 per cent.

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[1] Hawaii Agr. Exp. Sta. 1929, Bul. 60.

[2] Loc. cit.

ROOTS OF THE SPURGE FAMILY

(*Euphorbiaceæ*)

Characteristic of the family is the milky juice or latex. Several species of *Hevea* yield latex from which India rubber is made. A number of drugs, notably castor oil, croton oil, and cascarilla bark, are the products of members of the group.

Food plants are represented by emblic and bignay, described under Fruits, by candlenut, described under Oil Seeds in Volume I, and, most important of all, by cassava which in its root stores up starchy food for millions.

CASSAVA

Manihot spp.

Fr. Cassave. It. Manioca. Ger. Kassava.

Two species are recognized, the bitter cassava (*Manihot utilissima* Pohl) and the sweet cassava (*M. Aipi* Pohl = *M. dulcis* Pax var. *Aipi* Pax); however, as with many cultivated plants, it is not usually possible to determine the botanical origin of the numerous varieties. Bitter cassava contains hydrocyanic acid and possibly other poisonous constituents, but these disappear on drying the pulped root in the sun or on cooking. Sweet cassava contains no hydrocyanic acid or a negligible amount and is prepared for the table like the sweet potato and other root vegetables.

From both bitter and sweet cassava are prepared cakes, meal, starch (see Volume I), and agglutinated starch commonly known as tapioca or manioca. The yield of roots is enormous, those of a single plant ranging up to 15 kilos and the production per acre up to 20,000 kilos.

MACROSCOPIC STRUCTURE.—The plant is shrubby with palmate *leaves* suggesting those of the horse-chestnut but with lobes more deeply parted. The long fleshy *roots* reach 8 cm. in diameter and over 1 meter in length. Although the plant has a milky juice, this is not conspicuous in the root as the cortex and phloem are thin, the cambium layer being only 1 to 2 mm. from the surface.

MICROSCOPIC STRUCTURE.—Cassava or tapioca starch (see Volume I) has been often described, but no literature on the cellular tissues is available. The following is based on an examination of the dried root of sweet cassava grown in Florida.

Cork.—This forms a coat up to 20 or more cells thick, the walls in the outer layers being thicker and of a deeper brown color than those in the inner layers.

Cortex.—The cells of the *ground tissue* are often transversely elongated but in longitudinal section are isodiametric. *Stone cells* with walls much thinner than the lumen occur in the outer layers, occasional *crystal cells* further inward.

Phloem.—The *ground tissue* of the bundle proper is of nearly isodiametric cells, with little or no longitudinal elongation, in radial rows. The medullary cells are radially elongated. *Sieve tubes* and *latex tubes* are not clearly differentiated in cleared preparations of the dried material. It is stated that sweet cassava root with a low percentage of hydrocyanic acid contains a relatively small amount of latex.

Xylem.—*Vessels* occur at wide intervals, especially near the cambium. They are mostly finely reticulated, up to 200 μ in diameter, oval in cross section. In the central portion, broad, thin-walled *bast fibers* occur singly or in groups. The *ground parenchyma* is of nearly isodiametric more or less quadrilateral cells, in radial rows.

CHIEF STRUCTURAL CHARACTERS.—Root fleshy, with cambium layer near the surface.

Cork tissue brown, up to 20 or more cells thick. Cortex with stone cells and crystal cells. Vessels finely reticulated, up to 200 μ; broad, thin-walled bast fibers in central xylem. Starch abundant (see Volume I).

CHEMICAL COMPOSITION.—Moore,[1] in the examination of numerous samples representing different varieties of bitter and sweet cassava grown in Biloxi, Mississippi, and Miami, Florida, found a range of 50 to 78 per cent of moisture and 40 to 82 per cent of starch in the dry matter.

In the table below, the results on the fresh whole root are by Blasdale,[2] Adriano, Manahan, and Barros,[3] and Adriano;[4] on the dried whole root by Kling;[5] on the peeled root by Ewell and Wiley;[6] on cassava meal by Ammann,[7] Wiley,[8] the analyst of the Imperial

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[1] U. S. Dept. Agr., Bur. Chem. 1907, Bul. **106**.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[3] Philippine Agr. 1929, **18**, 119.

[4] Philippine J. Agr. 1933, **4**, 281.

[5] Landw. Vers.-Stat. 1913, **82**, 211.

[6] Am. Chem. J. 1893, **15**, 285.

[7] Compt. rend. 1920, **170**, 1333.

[8] U. S. Dept. Agr., Div. Chem. 1894, Bul. **44**.

Institute,[1] Tejeda,[2] and Hansson and Bengtsson;[3] and on cassava bread by Guabrado.[4]

COMPOSITION OF CASSAVA ROOT, MEAL, AND BREAD

	Samples	Water	Protein	Fat	N-f. ext.	Starch	Pentosans	Fiber	Ash
		%	%	%	%	%	%	%	%
Whole Root:									
Blasdale....	1	80.72	1.58	0.17	16.05*	12.01	......	0.85	0.63
A. M. and B.									
Angular...	1	74.18	1.10	0.18	22.29†	......	......	1.15	1.10
Kapo White	1	47.49	2.68	1.62	45.82‡	......	......	1.06	1.33
Adriano.....	Many	63.80	0.96	0.26	32.69	27.65	......	0.85	1.44
Dried Root:									
Kling.......									
Original...	1	11.28	1.35	0.27	83.27	73.56	2.04	1.98	1.85
Cleaned...	1	10.38	1.25	0.35	84.36	73.56	2.15	1.90	1.76
Peeled Root:									
E. and W...	1	61.30	0.64	0.17	36.50	30.98	......	0.88	0.51
Meal:									
Ammann....	6								
Min.......	....	10.72	2.93	......	....	70.00	......	2.10	2.48
Max.......	....	11.58	7.43	......	....	77.60	......	2.73	2.88
Aver......	....	**11.09**	**5.04**	......	....	**74.75**	......	**2.48**	**2.69**
Wiley.......	4								
Min.......	....	5.11	2.37	0.26	80.99	57.69	2.06	3.76	1.47
Max.......	....	7.05	3.42	0.50	85.86	70.13	3.09	6.53	3.04
Aver......	....	**5.76**	**2.98**	**0.42**	**83.80**	**64.28**	**2.63**	**5.08**	**1.96**
Imp. Inst.									
S. Nigeria §	1	11.4	2.1	1.1	82.1	......	......	1.8	1.6
Mauritius .	1	14.2	1.65	0.12	76.62	......	......	6.32	1.04
Tejeda......	1	12.20	1.80	0.92	78.08‖	65.78	......	4.20	2.80
H. and B....	1	......	1.79	0.61	80.05	......	......	......	.....
Bread:									
Guabrado...	1	26.00	11.25	8.60	49.11	......	......	4.00	1.04¶

* Reducing sugar 1.59, sucrose 0.76%. † Sucrose 0.58%. ‡ Sucrose 0.63%. § Known as *garri.* ‖ Dextrin 12.30%. ¶ P_2O_5 0.074%.

Protein.—Of a total protein of 1.25 per cent in the cleaned root, Kling[5] found that 1 per cent was true protein and 0.25 per cent was in other forms.

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[1] 1912, Bul. **10**, 562.

[2] Bol. agr. y camios Guatemala 1927, **6**, 464; Intern. Rev. Agr. 1928, **19**, 1057.

[3] Kgl. Landsbruks-Akad. Handl. Tid. 1929, **69**, 132.

[4] Sanidad y Beneficiencia 1922, **27**, 145; Bul. Agr. Intel. 1922, **13**, 1281.

[5] Loc. cit.

Hydrocyanic Acid.—Moore[1] reviews the work of Francis and of Carmody, government analysts of Trinidad, and of Cousins, government analyst of Jamaica, from 1877 to 1904, showing hydrocyanic acid in bitter varieties as high as 0.077 per cent but in sweet varieties usually less than 0.016 per cent. His own results on a number of varieties grown at Biloxi, Mississippi, show a range from 0.001 to 0.030 per cent and on those grown at Miami, Florida, from 0.0005 to 0.016 per cent. Collens[2] reports in the edible portion of sweet and bitter cassava roots respectively 0.0048 and 0.053 per cent. The hydrocyanic acid was evenly distributed when dug but after 3 days the portion nearest the stem contained twice as much as the terminal portion. Air drying caused an increase in the roots. Johnson[3] reports in the whole root 0.006 to 0.025, in the peeled root 0.007 to 0.021, and in the peel 0.015 to 0.042 per cent. Ammann[4] gives 0.002 to 0.008 per cent as the range in Cambodia roots, and Adriano[5] 0.02 per cent as the average of many analyses.

Phosphorus-Organic Compounds. *Phytin.*—In the root, Bagaoisan[6] found 0.92 to 1.99 per cent, dry basis.

Mineral Constituents.—An analysis of the ash of the peeled root, as reported by Wiley,[7] follows:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl	Sand	CO_2	C
%	%	%	%	%	%	%	%	%	%	%	%
41.63	1.20	10.64	7.35	0.66	15.58	3.73	0.94	2.75	7.15	9.14	0.31

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[1] Loc. cit.

[2] Dept. Agr. Trinidad and Tobago 1914, Bul. **14**, 54.

[3] Hawaii Agr. Exp. Sta. Rep. 1916, p. 24.

[4] Loc. cit.

[5] Loc. cit.

[6] Philippine Agr. 1932, **21**, 53.

[7] Loc. cit.

ROOTS OF THE PARSLEY FAMILY

(*Umbelliferæ*)

Four edible fleshy roots, developed by breeding from the normal forms, viz., parsnip, carrot, celeriac, and parsley, are here described. They are rich in starch or sugar, depending partly on the species and partly on the time when dug. Volatile oil is the characteristic flavoring constituent.

Classification.—Following are important food plants of the family, including not only root vegetables but also leaf and stem vegetables and fruit (seed) spices, grouped according to sub-family, tribe, and genus.

Cœlospermæ.
  I. *Coriandreæ.* *Coriandrum* (coriander [3]).

Campylospermæ.
  II. *Scandiceæ.* *Anthriscus* (chervil [2]).

Orthospermæ.
  III. *Daucineæ.* *Daucus* (carrot [1]).
  IV. *Cumineæ.* *Cuminum* (cumin [3]).
  V. *Peucedaneæ.* *Pastinaca* (parsnip [1]), *Anethum* (dill [3]).
  VI. *Angeliceæ.* *Angelica* (angelica [2]).
  VII. *Seselineæ.* *Fœniculum* (fennel [3], Florence fennel [2]).
  VIII. *Ammieæ.* *Pimpinella* (anise [3]), *Carum* (caraway [3]), *Petroselinum* (parsley [1, 2]), *Apium* (celery [1, 2, 3]), *Cryptotænia* (mitsuba [2]).

COMPARATIVE MACROSCOPIC STRUCTURE.—Normal roots are either long and gradually tapering (some varieties of carrot and most varieties of parsnip), short and broad (turnip-rooted parsnip and celeriac), or club-shaped, abruptly narrowing to a tail-like root end (some varieties of carrot). Celeriac has a tangle of secondary roots, and all the species, if grown in hard, stony soil, tend to branch. The surface of the roots is smooth except for numerous narrow, transversely elongated lenticel-like markings, from the center of which spring thread-like rootlets.

Cut transversely the xylem and phloem are seen to be sharply separated by the cambium layer which in ordinary sized roots is from half to one-quarter of the distance from the periphery to the center; consequently cortex and phloem form a greater proportion of the whole root than in cruciferous roots. The outer cortex is usually of a more uniform color than the inner cortex, phloem, and xylem, which are commonly mottled and in the case of the xylem marked by radiating streaks. Breaking through the tissues are the bundles and accompanying elements of the lateral rootlets. These, in a root like celeriac, cause distortion of the zones which in other members of the group are quite uniform.

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[1] Root (vegetable).

[2] Stem and leaf (vegetable).

[3] Fruit (spice).

COMPARATIVE MICROSCOPIC STRUCTURE.—The cell forms are so nearly alike in all the common roots of this family that the description given for parsnip suffices for all with suitable notation of exceptions.

COMPARATIVE CHEMICAL COMPOSITION.—The solids of umbelliferous root vegetables consist chiefly of reducing sugars and sucrose, the former usually predominating. A moderate amount of starch is present during the growing season, but this disappears during storage at a little above freezing or, in the case of the parsnip, wintering in the ground. A minute amount of volatile oil contributes flavor. Orange-colored carrots are among the most abundant sources of carotene; white carrots and parsnips, however, contain little or no pigment.

PARSNIP

Pastinaca sativa L.

Fr. Panais. Sp. Chirivia. It. Pastinaca. Ger. Pastinake.

The parsnip is a native of temperate Europe. As in the carrot, the fleshy development of the root has been brought about by breeding and is lost after a time when the plant escapes from cultivation. The roots may be dug in the Fall and stored for Winter use, or they may be left in the ground over Winter and dug in the Spring. The latter procedure is commonly practiced, the roots being sweeter and of improved flavor after freezing and thawing.

As a stew and soup vegetable, the parsnip is used like the carrot but is not so popular. It is less likely to have a strong taste, even when grown to a large size, than the carrot, but its greater sweetness is objectionable to some. In the Spring, after Winter vegetables are gone and before fresh ones arrive, parsnips fried brown are relished especially with salt meat, but few care for more than occasional indulgence in the dish.

Parsnips are valuable for Spring feeding of farm animals, the problem of storage being solved by leaving the roots in the ground until needed.

MACROSCOPIC STRUCTURE.—From the carrot the parsnip is distinguished by its broad leaflets, the yellow-flowered umbel, and the smooth and more flattened winged fruits which do not form a nest-like cluster. The *root* varies from white to yellow and does not run into orange or red shades so common in carrots. The ordinary varieties have a long tapering root which, when grown in deeply tilled soil, is usually unbranched, often reaching 400 cm. in length. Another type has a top-shaped root usually broader than long. On the surface, which is otherwise smooth, are numerous transverse lenticel-like markings or eyes, often several centimeters long and about 1 mm. broad in the middle, tapering toward the ends, from the center of which spring one or more thread-like rootlets.

In cross section (Fig. 20) the cambium zone, located about half way from the periphery to the center, is well marked by the greenish color of the phloem adjoining on the outside and the yellow color of the zone of xylem rays adjoining on the inside. The cortex and outer phloem are mottled white or cream-colored, and the core of the root is white and gray in irregular radiating streaks following along the medullary rays, the peculiar appearance being due to the presence of air in groups of cells. Here and there, as shown in Fig. 20, transverse bundles running to the lateral rootlets break through the zones of tissues.

The *stem* is represented by a short crown covered with leaf bases or leaf scars.

MICROSCOPIC STRUCTURE.—The description which follows is based on the examination of roots dug during the growing season. When the roots were allowed to remain in the frozen ground over Winter and dug after the frost was out of the ground in the Spring, the starch grains were found to have entirely disappeared, having been converted into soluble carbohydrates. Whether this change takes place in regions where the ground does not freeze was not determined.

Cork (Figs. 21 and 22, *S*; Fig. 23).—Several rows of cork cells, increasing in radial diameter inward, are seen in cross section. In surface view they are mostly transversely elongated, usually of irregularly quadrilateral form and arranged end to end. In the eyes, about the base of the rootlets, the cells are isodiametric.

Cortex (Figs. 21 and 22, *C*).—The cells of the outer cortex are distinguished in cross section from those of the cork by their greater size, thicker walls, and muriform arrangement. Starch is absent or present in small amount in the cortex except where it passes into the phloem ring.

Phloem (Fig. 21, *P*; Fig. 22).—Longitudinal sections show the rounded (am^1) and rectangular (am^2) *starch cells*, forming the parenchyma of the phloem proper and the cells of the medullary rays (m)

also containing starch, the inconspicuous *sieve tubes* with plates, the narrow *companion cells*, the *substitute fibers* (*f*) with blunt points, somewhat thickened walls, diagonal pits, and granular contents, and the *oil ducts* (*ol*) accompanied by rounded cells containing *aleurone grains* (*al*) up to 4 μ in diameter. The *starch grains* (*am*, am^1, am^2), absent in the cambium region and cells about the oil ducts, are partly round or rounded polygonal, up to 10 μ, those in the medullary rays being smaller than those in the phloem rays, and partly minute combined to form aggregates up to 20 μ. Small aleurone grains are evident in the Spring after the disappearance of the starch.

Cambium (Figs. 21 and 22, *Cm*).—The several layers of narrow elongated cells are starch free.

Xylem.—The walls of the *parenchyma* are thin in young roots but thicken with growth, contrasting strongly with the walls of the medullary rays which remain thin. Starch is absent or sparingly present, except in the Autumn when it is confined chiefly to the medullary rays. The *vessels* (Fig. 21, *v*) are of two types: (1) *reticulated* (Fig. 22, *r*)

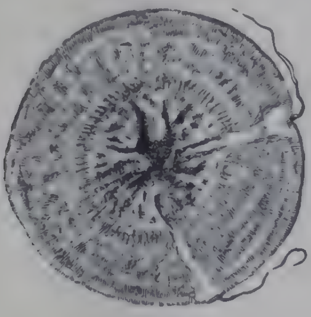

Fig. 20.

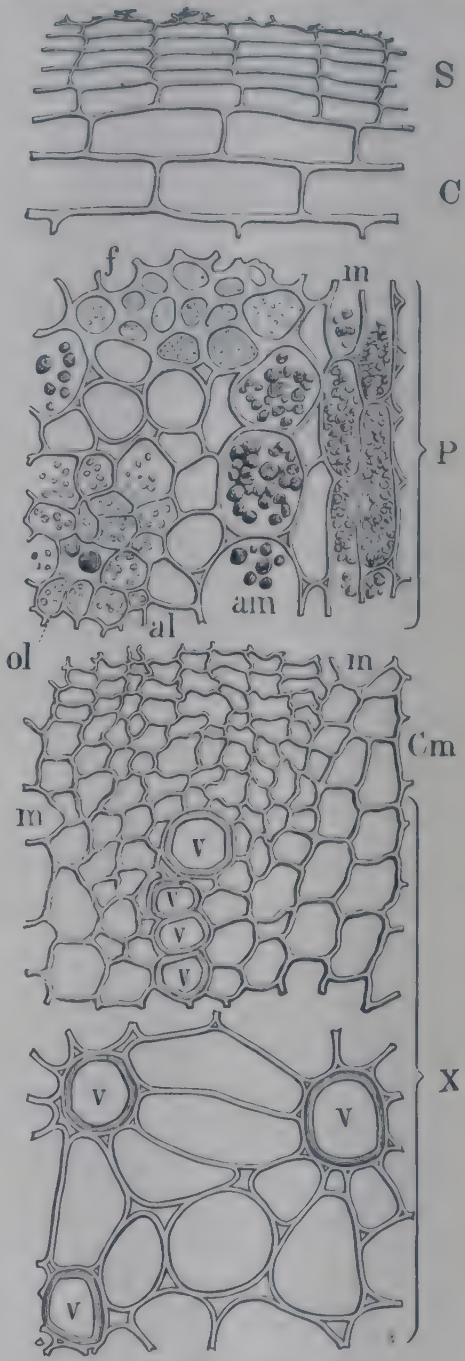

Fig. 21.

Fig. 20.—Parsnip. Root in cross section showing xylem rays, adjoining the cambium midway between the periphery and the center, and lateral bundles extending through cortex to rootlets. × 1. (A.L.W.)

Fig. 21.—Parsnip. Root in cross section. *S* cork. *C* outer cortex. *P* phloem: *f* substitute fibers, *ol* volatile oil cavity, *al* aleurone grains, *am* starch grains, *m* medullary ray with starch grains. *Cm* cambium. *X* xylem: *v* vessels, in center of root surrounded by radiating parenchyma. × 160. (A.L.W.)

with a tendency to *spiral*, up to 75 μ, occurring mostly in the outer zone, and (2) pitted (*pi*) or *scalariform*, up to 100 μ, with several (up to ten) rows of slit-like pits, occurring mostly in the inner tissues and forming centers for radiating parenchyma. The lateral vessels running into the rootlets are narrow, many of them being spiral.

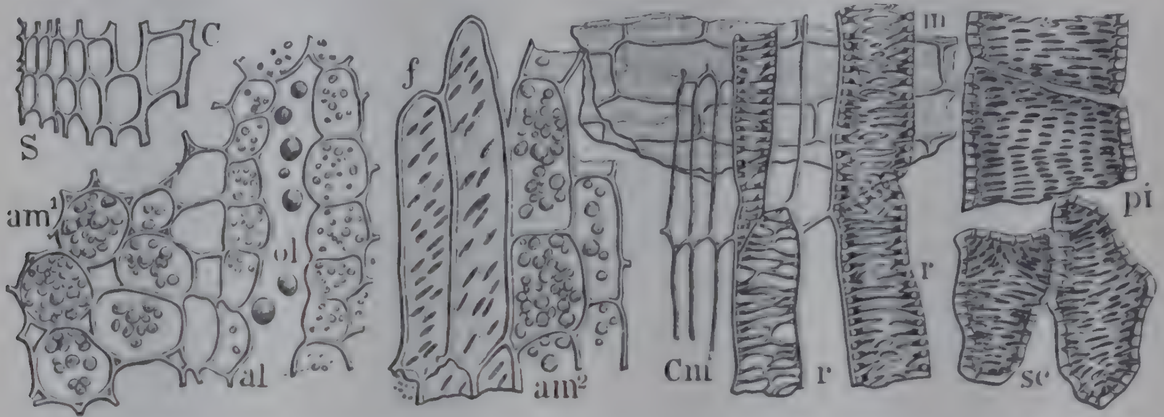

Fig. 22.—Parsnip. Elements of root in longitudinal-radial section. *S* cork. *C* outer cortex. Phloem: am^1, am^2 starch cells, *ol* volatile oil duct adjoined by cells containing *al* aleurone grains, *f* substitute fibers. *Cm* cambium. Xylem: *r* reticulated vessels, *pi* pitted vessels, *sc* sclerenchyma cells (modified vessels), *m* medullary ray. × 160. (A.L.W.)

Chief Structural Characters.—Root long tapering or short; color white or yellowish; eyes transversely elongated with rootlets.

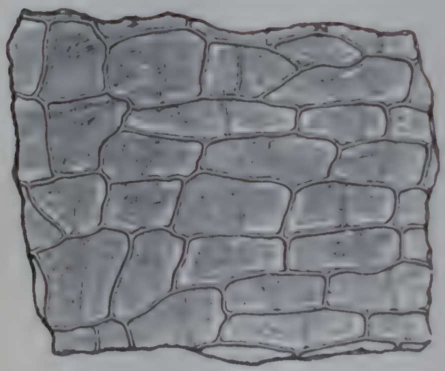

Fig. 23.—Parsnip. Cork in surface view showing cells in rows, transverse walls of second layer hidden by those of outer layer. ×160. (A.L.W.)

Cork and cortex cells mostly transversely elongated, quadrilateral. Phloem with substitute fibers and volatile oil ducts in addition to sieve tubes, companion cells, and parenchyma. Starch present in Autumn in parenchyma, including medullary rays, of phloem zone. Vessels mostly spiral-reticulated, the larger forms, up to 100 μ, with short pits side by side in longitudinal rows.

CHEMICAL COMPOSITION.—The average composition of whole parsnips, as given by Lindsey, Smith, and Beals,[1] and the average and limits of the edible portion, as given by Atwater and Bryant,[2] are tabulated on the next page.

Carbohydrates.—While sugar in potatoes imparts an unpleasant flavor, in parsnips, as in sweet potatoes, the reverse is true. The disappearance of starch in the roots left in the ground over Winter has been noted under Microscopic Structure.

[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul. p. 13.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

COMPOSITION OF PARSNIPS

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
L., S., and B.:	6						
Aver.		80.0	2.2	0.4	14.8	1.3	1.3
A. and B.:	3						
Min.		79.5	1.4	0.2	8.5	2.5*	0.7
Max.		89.2	1.9	0.8	16.7	2.5*	1.9
Aver.		83.0	1.6	0.5	13.5	2.5*	1.4

* 1 analysis.

Boswell[1] found that storage at just above the freezing point (1.5° C.) for 16 days produces changes similar to those that take place when the roots are left in the ground over 2 months. The hydrolysis of starch and other polysaccharides proceeds more rapidly at 1.5° C. than at the usual temperature of soil or cellar. While the roots are actually frozen the changes are slow. Quantitative results by Boswell amplify these observations.

Mineral Constituents.—Following is an analysis on the basis of the fresh vegetable reported by Haskins:[2]

Water	K_2O	Na_2O	CaO	MgO	P_2O_5
%	%	%	%	%	%
80.3	0.62	0.01	0.09	0.05	0.19

Minor Mineral Constituents. *Iron.*—Root 10.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Copper.—Root 1.2 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

CARROT

Daucus carota L.

Fr. Carotte. Sp. Zanahoria. It. Carota. Ger. Möhre.

From the wild carrot, a native of the Old World and now a cosmopolitan noxious weed, has been derived the fleshy-rooted form now regarded as one of the most wholesome of vegetables. The root is eaten during the growing season as well as throughout the Winter. It has excellent keeping qualities.

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[1] Maryland Agr. Exp. Sta. 1923, Bul. **258**, 61.

[2] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul. p. 95.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Ibid. 1929, **82**, 465.

Carrots are not commonly canned alone in the United States but are an ingredient of canned soups and in France are one of the vegetables used in canned mixed vegetables (macédoine des légumes). Formerly, and possibly still in certain countries, dried carrots were used as an adulterant of chicory and coffee, and carrot pulp as a stock for imitation jams and preserves. As a cattle food, carrots are of recognized value although not extensively used.

The inflorescence and fruit of the wild form, the latter sometimes contaminating grain, are described under Oil Seeds, Volume I.

MACROSCOPIC STRUCTURE.—As ordinarily found in the market, the carrot is orange colored and the parsnip is white; there are, however, white carrots differing little in color from the parsnip, also there are red varieties. The popular varieties for human consumption are short or half long, abruptly narrowing to a slender terminal, but other varieties, including some used for stock food, taper gradually to the tip like the parsnip. Narrow, lenticel-like, transversely elongated eyes, with rootlets like those of the parsnip, occur on the surface.

The mottled appearance of the cortex and outer phloem and the radiating appearance of the xylem zone, both due to differences in turgescence, are more striking in orange-colored carrots than in white carrots and parsnips. Common garden varieties show on the transversely cut surface an outer ring, 1 to 2 mm. thick, of a dark orange color (*cortex*) passing into a zone mottled with lighter orange (*outer phloem*) and then into a zone of nearly uniform greenish yellow color (*inner phloem*) adjoining the cambium layer. The *xylem zone* is dark orange with lighter-colored rays. Examination of a cross section 1 mm. or less thick held up to a bright light shows a very different color scheme. The parts that appear dark on the cut root are translucent, of a light orange color in the parts outside the cambium layer and nearly colorless in the xylem zone, whereas the parts which appear light colored on the cut root are opaque. Rubbing the cut surface with the back of the finger-nail produces a uniform color in both cases or boiling the root before sectioning brings about the same result.

MICROSCOPIC STRUCTURE.—Except for the presence of chromatophores in orange or red carrots, the more robust development of certain tissues of the parsnip, and differences in the occurrence of starch, the microscopic characters of the carrot are practically the same as those of the parsnip.

The *chromatophores* (Fig. 24, I), or orange pigment crystals, of the carrot attracted the attention of the early histologists and are still among the best-known examples. *Carotene*, the substance forming the crystals, derived its name from this root. It is in the cortex that the chromatophores are usually most abundant, their presence being especially noticeable in roots of highly colored varieties dug in the Fall after the starch has disappeared. Aside from their color, they are characterized by their wedge-shaped, spindle-shaped, needle-shaped, and prismatic forms.

Guilliermond[1] has shown that, in the formation of carotene, granular mitochondrias are first differentiated into leucoplasts from which starch grains are formed. In the remaining part of the leucoplast, pigmented elements of a more or less crystalline nature appear, after which the starch grains are slowly absorbed and the leucoplasts disappear little by little. Tswett[2] believes that none of the microscopic tests for carotene is satisfactory. The potash method of Molisch and the resorcin methods of Tswett are not specific tests for carotene but for lipochromes of the carotene group. Tswett also doubts the purity of the red crystals formed in the acid test of Frank and Tschirch.

The relation of carotene to vitamin A is now a subject of extensive research. See Introduction.

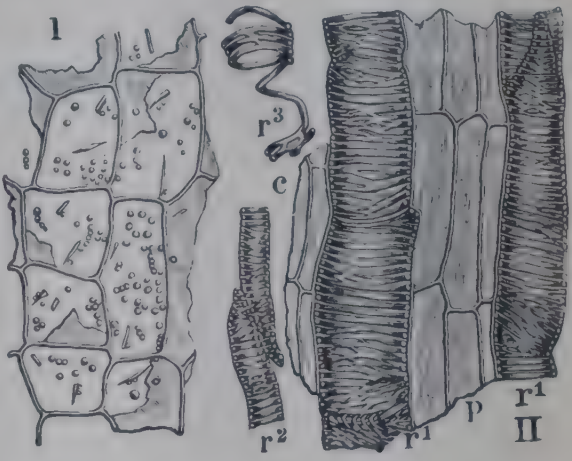

Fig. 24.—Carrot. I cortex in radial longitudinal section showing rounded starch grains and crystalline chromatophores. II outer xylem zone in radial longitudinal section: r^1, r^2, and r^3 reticulated vessels, p parenchyma, c cambium. × 160. (A.L.W.)

Starch grains (Fig. 24, I), as noted above, occur in the same cells with the chromatophores. Those in the cortex are small, occurring either singly or in small aggregates. Further inward, especially in the phloem parenchyma and medullary cells outside the cambium ring, they are somewhat larger, but so far as observed they are neither so abundant nor so large as in the parsnip and are further distinguished by their gradual disappearance at later stages of growth. The *substitute fibers* of the carrot, at least as grown for the table, are commonly not so thick-walled as those of the parsnip, and the same difference applies to the xylem parenchyma, especially the cells accompanying the vessels. The maximum breadth of the *vessels* (Fig. 24, r^1, r^2, r^3) is also less than in the parsnip, and the presence of several rows of short pits, such as are shown in Fig. 22, *pi*, is unusual except in the center of rank-growing, coarse-textured varieties used for stock feeding.

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[1] Compt. rend. 1912, **155**, 411.

[2] Ber. deut. bot. Ges. 1911, **29**, 630.

It always should be remembered that since roots of biennial plants dug during or even after the first season's growth have not, like mature fruits and seeds, reached a definite limit of development or ripeness, cells and cell contents are more or less variable in form and size.

CHIEF STRUCTURAL CHARACTERS.—Root long and tapering or short and abruptly narrowed; color red-orange to yellow or white.

Chromatophores in cortex and phloem. Substitute fibers and xylem parenchyma thinner-walled and vessels usually smaller than those of parsnip. Starch largely disappears by Fall.

CHEMICAL COMPOSITION.—Lindsey, Smith, and Beals[1] record the average composition of 15 samples of carrots, v. Schleinitz[2] gives the average composition of early and late varieties, and Atwater and Bryant[3] show the range and average composition of the edible part of 18 samples.

COMPOSITION OF CARROTS

	Samples	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%	%
L., S., and B.:								
Aver.	15	89.0	1.0	......	0.1	7.9	1.0	1.0
v. Schleinitz:								
Late varieties, aver.	....	89.62	0.90	0.74	0.31	7.45	0.93	0.79
Early varieties, aver.	....	89.45	1.15	0.76	0.28	7.17	1.10	0.85
A. and B.:								
Edible part (80%)	18							
Min.	....	83.1	0.7	......	......	6.5*	0.6	0.6
Max.	....	91.1	2.0	......	0.7	13.8*	2.3	1.6
Aver.	....	88.2	1.1	......	0.4	9.3*	1.1†	1.0

* Includes fiber. † 15 samples.

For several years Werenskiold analyzed roots submitted by Norwegian agricultural societies, the results for the year 1893[4] being of special interest because of the wide range in percentages of sucrose and reducing sugars.

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[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul. p. 13.

[2] Landw. Jahrb. 1918, **52**, 131.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[4] Chem. Control Sta. Christiania, Rep. 1893, p. 11.

COMPOSITION OF CARROTS (WERENSKIOLD)

(Results on dry basis)

	Samples	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Fiber	Ash
		%	%	%	%	%	%	%	%
Min. . .	21	83.73	5.47	0.49	68.34	13.37	10.76	7.87	6.52
Max. . .	21	89.72	12.19	2.10	74.90	45.53	34.61	15.83	10.02

Expressed in percentage of the total nitrogen, the amide nitrogen ranged from 37.5 to 60.0 per cent.

Changes in Composition During Development.—The following analyses[1] of Early Long Orange carrots were made during different stages of development.

COMPOSITION OF CARROTS AT DIFFERENT STAGES OF DEVELOPMENT

Date	Weight	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	g.	%	%	%	%	%	%
June 9.	0.4	88.40	1.26	0.44	6.71	0.62	2.57
June 19.	0.9	88.20	1.17	0.72	6.74	1.62	1.55
June 26.	16.0	87.40	1.18	0.34	8.55	0.99	1.54
July 3.	18.2	87.70	1.22	0.57	7.64	1.51	1.36
July 10.	38.0	87.30	0.98	0.46	9.03	0.90	1.33
July 20.	74.0	87.50	1.03	0.66	8.44	1.11	1.26
Oct. 15.	157.0	84.30	1.66	0.50	10.74	1.25	1.55
Oct. 25.	697.0	86.80	1.99	0.62	7.70	1.55	1.34

Analyses made by Platenius[2] 60 and 168 days after planting show respectively as follows: protein 11.34, 8.67; true protein 7.71, 4.79; reducing sugars 23.24, 8.46; sucrose 16.53, 33.91; starch 2.52, 1.48; fiber 9.50, 7.30; lignin 2.98, 1.95; calcium 0.066, 0.061; and phosphoric acid 1.356, 1.031 per cent dry basis.

Composition of Varieties.—Analyses by Shutt[3] of the same varieties grown two successive years show marked differences in sugar content but much smaller differences in the content of dry matter.

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[1] U. S. Dept. Agr. Rep. 1883, p. 239.

[2] Plant Physiol. 1934, 9, 671.

[3] Canada Dept. Agr. Dom. Chem. Rep. 1910, p. 211; 1911, p. 179.

Composition of Varieties of Carrots (Shutt)

	1909			1910		
	Water	Solids	Sucrose	Water	Solids	Sucrose
	%	%	%	%	%	%
Ontario Champion	89.17	10.83	3.19	89.04	10.96	5.92
Half Long Chantenay	88.44	11.56	3.36	89.64	10.36	3.44
Improved Short White	90.46	9.54	1.38	89.85	10.15	2.33
Mammoth White Intermediate	89.90	10.10	2.08	89.97	10.03	3.25
White Belgian	89.63	10.37	2.06	90.62	9.38	1.22

Losses on Boiling.—Snyder[1] has shown that on boiling carrots a great loss of nutrients takes place which can be partially avoided by cooking the roots whole.

Losses on Cooking Carrots (Snyder)

(Percentages of total amount of each constituent)

	Solids	Total N	Sugars	Ash
	%	%	%	%
Small pieces	29.9	42.5	26.0	47.3
Medium pieces	23.5	27.5	26.5	37.3
Large pieces	20.2	20.0	15.5	29.3

Proteins.—According to Cohn, Gross, and Johnson,[2] carrot juice has the same isoelectric point as a solution of the globulin tuberin as it exists in potato juice, the chief distinction being in the large precipitate formed with alkali which nearly equals that formed with acid.

Isolation and study of carrot proteins, it is hoped, soon will be undertaken.

Nitrogenous Bases.—*Choline* is stated by Schulze and Trier[3] to occur in the carrot. Doubtless other bases are present.

Carbohydrates.—Analyses of dehydrated carrots by Falk[4] show an apparent increase in starch at the expense of alcohol- and water-soluble carbohydrates. This may be due to the failure of water and alcohol to penetrate into the hard lumps.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1897, Bul. **43**, 7.

[2] J. Gen. Physiol. 1919, **2**, 145.

[3] Z. physiol. Chem. 1912, **81**, 53.

[4] J. Ind. Eng. Chem. 1919, **11**, 1133.

CARBOHYDRATES OF FRESH AND DEHYDRATED CARROTS (FALK)
(Percentages of total carbohydrates)

	Reducing sugars, direct	Total sugars *	Dextrin and soluble starch	Insoluble starch (by dif.)
	%	%	%	%
Fresh	57.1	92.2	2.7	5.1
Air-dried	53.8	85.7	3.7	10.6
Vacuum-dried	48.5	74.2	4.2	21.6

* Total reducing sugars after hydrolysis of alcohol extract.

Pentosans.—Sebelien[1] found in carrots 8.43 per cent of pentosans and 2.59 per cent of methylpentosans, on the dry basis.

Pectins.—Results obtained by Buston and Kirkpatrick[2] indicate that the percentage of protopectin in the stele or central cylinder is much higher than in the cortex, although that of the true or middle lamella pectin is practically the same in both parts.

Phosphorus-Organic Compounds. *Phytin.*—In the root Bagaoisan[3] found about 5.27 per cent, dry basis.

Colors. *Carotene.*—The nature and chemical structure of the two forms of carotene, α and β, are considered in the Introduction.

Determinations, made by Smith and Milner[4] on α-carotene from carrot root, gave melting point 182.3 to 182.7° C. and specific rotation in benzene at 16 to 19° C. with C light 297 to 311°.

Mineral Constituents.—Following is an analysis on the basis of the fresh vegetable reported by Haskins:[5]

Water	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5
%	%	%	%	%	%	%
89.8	0.92	0.51	0.06	0.07	0.02	0.09

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[1] Chem. Ztg. 1906, **30**, 401.

[2] Ann. Bot. 1931, **45**, 519.

[3] Philippine Agr. 1932, **21**, 53.

[4] J. Biol. Chem. 1934, **104**, 437.

[5] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul. p. 95.

Minor Mineral Constituents. *Iron.*—Root 10 mg. per kilo, fresh basis (Häusermann).[1] Root 2.2 mg. per kilo, fresh basis, 17.6 mg. per kilo, dry basis (Guérithault).[2] Root, 8 samples, 111 to 330, aver. **204** mg. per kilo; leaves, 5 samples, 355 to 765, aver. **517** mg. per kilo, dry basis (Remington and Shiver).[3] Root 10.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[4] Root, 2 samples, 4.3, 6.4 mg. per kilo, fresh basis (Toscani and Reznikoff).[5]

Aluminum.—Root, young 30 mg. per kilo, old 22 mg. per kilo, dry basis (Bertrand and Lévy).[6]

Manganese.—Root, 8 samples, 19.1 to 90.9, aver. **42.2**; leaves, 5 samples, 51.6 to 199.1, aver. **121.1** mg. per kilo, dry basis (Remington and Shiver).[3]

Copper.—Root 11 mg. per kilo, dry basis (Maquenne and Demoussy).[7] Root, 8 samples, 7.5 to 14.4, aver. **10.7**; leaves, 5 samples, 9.6 to 21.8, aver. **12.4** mg. per kilo, dry basis (Remington and Shiver).[3] Root 2.2 mg. per kilo, fresh basis (Guérithault).[8] Root 0.8 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[9]

Zinc.—Root 5 mg. per kilo, air-dry basis (Birckner).[10] Root 1.1 mg. per kilo, fresh basis (Bertrand and Benzon).[11] Root 29.5 to 43.1 mg. per kilo, dry basis (Hubbell and Mendel).[12]

Arsenic.—Root 0.05 mg. per kilo, fresh basis (Jadin and Astruc).[13]

Iodine.—Root, present (Winterstein).[14]

TURNIP-ROOTED PARSLEY

Petroselinum hortense Hoffm.

Hamburg or turnip-rooted parsley is a fleshy-rooted variety of parsley analogous to celeriac and like the latter of much less importance than the leafy forms.

MACROSCOPIC STRUCTURE.—The *root* resembles a small parsnip in appearance and flavor.

MICROSCOPIC STRUCTURE.—The *starch grains* range up to 10 μ and occur singly or in small aggregates. The vessels range up to 65 μ and are mostly reticulated or with several rows of pits. Other elements correspond with those of the parsnip.

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[1] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[2] Compt. rend. 1920, **171**, 196.

[3] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Nutrition 1934, **7**, 79.

[6] Compt. rend. 1931, **192**, 525.

[7] Ibid. 1920, **170**, 87.

[8] Bul. soc. hyg. aliment. 1927, **15**, 386.

[9] J. Biol. Chem. 1929, **82**, 465.

[10] Ibid. 1919, **38**, 191.

[11] Bul. soc. hyg. aliment. 1928, **16**, 457.

[12] J. Biol. Chem. 1927, **75**, 567.

[13] Compt. rend. 1912, **155**, 291.

[14] Z. physiol. Chem. 1918, **104**, 54.

CELERIAC

Apium graveolens L. var. *rapaceum* DC.

Fr. Céleri-rave. Sp. Apio nabo. It. Sedano rapa. Ger. Knoll-Sellerie.

Turnip-rooted celery or celeriac is a variety of the same species that produces edible leaf stalks (see Celery) and celery seed (see Volume III). It is much used in Europe but, although cataloged by American seedsmen and grown to some extent on a commercial scale, is little known except by the foreign population.

Used in soups and stews it imparts a desirable flavor; as a salad vegetable, cooked or raw, it also has merit.

MACROSCOPIC STRUCTURE.—The *main root* is short and broad with numerous secondary roots at the bottom and along the sides, forming a tangled mass. Some seedsmen advertise smooth varieties, but their illustrations of these are far from smooth compared with well-grown parsnips or carrots.

The *secondary roots* are sometimes trimmed off close to the main root before marketing.

MICROSCOPIC STRUCTURE.—The numerous secondary roots, some springing from well up on the main root, naturally bring about much distortion of the zones of tissues which in the parsnip, carrot, and other roots, when unbranched, show an orderly arrangement. In the form and kind of tissue elements the root corresponds closely with the parsnip, but starch disappears completely if the roots are left in the ground until Fall.

CHIEF STRUCTURAL CHARACTERS.—Main root short, white, with numerous much-tangled secondary roots.

Structure practically like that of parsnip except that arrangement in zones is less orderly, owing to the secondary roots, and starch disappears by Fall.

CHEMICAL COMPOSITION.—See Celery.

Minor Mineral Constituents. *Manganese.*—Root 150 mg. per kilo, dry basis (Quartaroli).[1]

Copper.—Root 133 mg. per kilo, dry basis (Quartaroli).[1]

Zinc.—Root 2.1 mg. per kilo, fresh basis (Bertrand and Benzon).[2]

Iodine.—Present (Winterstein).[3]

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[1] Ann. chim. appl. 1928, **18**, 47.

[2] Bul. soc. hyg. aliment. 1918, **16**, 457.

[3] Z. physiol. Chem. 1918, **104**, 54.

ROOT-TUBERS OF THE MORNING-GLORY FAMILY

(*Convolvulaceæ*)

THE sweet potato, the one species of importance as a food, is described below.

Starch grains, *oxalate rosettes*, and *latex* are the visible cell contents.

SWEET POTATO

Ipomœa Batatas Lam. = *Batatas edulis* Chois. = *Convolvulus Batatas* L.

Fr. Patate douce. Sp. Batata. It. Patata. Ger. Süsse Kartoffel.

Believed to be a native of tropical America, the sweet potato, a creeping or less often twining plant, is now cultivated throughout the tropics and sub-tropics. It is a popular root vegetable in the United States, being to the South what the common or white potato (known in the South as Irish potato) is to the North. Although the crop may be grown as far north as southern New England, its successful culture is limited to warmer sections which supply both the northern and southern markets, also the canneries where the pared vegetable is packed.

Two types of sweet potato are cultivated: (1) the mealy or dry, commonly with light yellow flesh, and (2) the soft or moist, with light yellow or deep orange flesh, especially rich in sugar. The former is preferred in the North, the latter in the South.

Commonly the fleshy root is boiled or baked without paring. It is also baked, after paring, with sugar, the dish being known as "candied potatoes." Sweet potato pies resemble closely those made from pumpkins and squashes.

MACROSCOPIC STRUCTURE.—Most of the earlier authors and Artschwager[1] among recent authors consider that the sweet potato is a tuberous root or root-tuber and not a true (stem) tuber. Haak[2] and Kamerling,[3] however, believe that it is a true (stem) tuber. If it is a true tuber, the arrangement of the bundle elements and the nature of the vessels are most unusual.

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[1] J. Agr. Res. 1924, **27**, 157.

[2] Plantenkunde van Indië, Semarang, 1892, p. 186.

[3] B. deut. bot. Ges. 1914, **32**, 352.

The *root-tubers* are more or less spindle-shaped with white, yellow, salmon-red, or purple skin, and flesh varying from white or cream colored to orange, the color being intensified by cooking. Even when the flesh on the whole is light colored, the cambium zone, situated about 3 mm. from the surface, is dark orange and the xylem rays are medium orange.

MICROSCOPIC STRUCTURE.—Earlier authors on the microscopy of foods confined their attention to the starch. Artschwager[1] describes the whole root with notes on internal breakdown.

Cork (Fig. 25, *S*; Fig. 26).—As seen in strippings from the boiled vegetable, the cells approach quadrilateral in form and are arranged for the most part in transverse rows. On treatment with sodium hydroxide, they become golden yellow. Cross sections show that the layer is several cells thick.

Cortex (Fig. 25, *C*).—*Starch parenchyma* makes up the bulk of the tissue. The cells

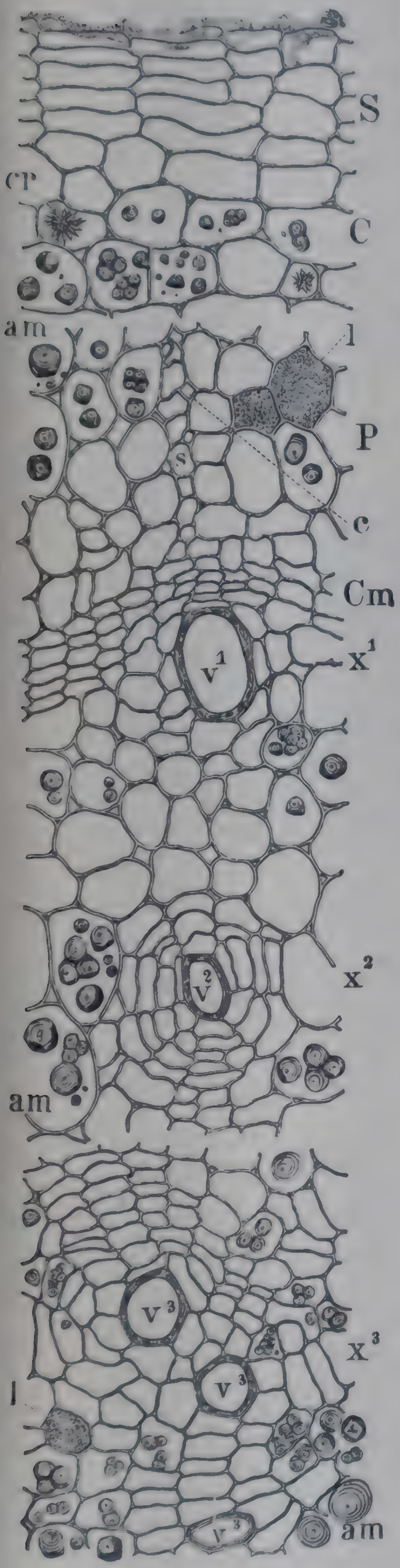

FIG. 25.

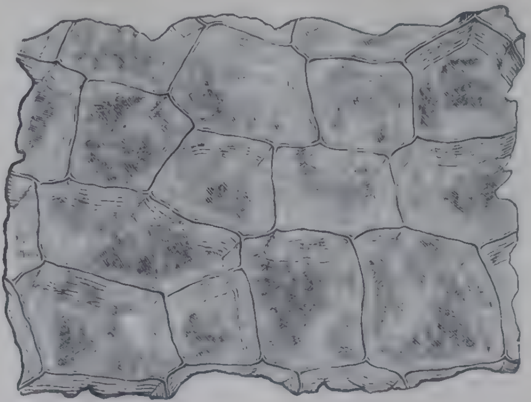

FIG. 26.

FIG. 25.—Sweet Potato. Tuberous root in cross section. *S* cork. *C* outer cortex with *am* starch cells and *cr* crystal cell. *P* phloem zone with *s* sieve tubes, *c* companion cells, and *l* latex cells. *Cm* cambium, x^1, x^2, and x^3 xylem groups with v^1, v^2, and v^3 vessels. × 160. (A.L.W.)

FIG. 26.—Sweet Potato. Cork of tuberous root in surface view. × 160. (A.L.W.)

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[1] Loc. cit.

are rounded with small intercellular spaces at the angles, and the starch grains (*am*) are of the tapioca type, increasing in size from without inward, reaching a maximum of about 50 μ (see Commercial Starches, Volume I). *Crystal cells* (*cr*), each containing an oxalate rosette with points of the crystals unusually long and slender, and *latex cells*, such as described below, are distributed among the starch cells.

Phloem (Fig. 25, *P*; Fig. 27).—The *sieve tubes* (*s*) and *companion cells* (*c*) are of typical form. As seen in longitudinal section, the *starch cells* (Fig. 27, *p*) are for the most part longitudinally elongated and arranged in radial rows. The *starch grains* (*am*) are like those of the inner cortex.

Of special interest are the *latex cells* (Figs. 25 and 27, *l*), which are readily distinguished from the parenchyma cells by their darker color and their granular contents staining yellow with iodine in potassium iodide. They are true cells, not latex tubes such as are common in composite roots, and the latex appears to be of a resinous nature. See De Bary[1] and Sachs[2] and the authors quoted by them.

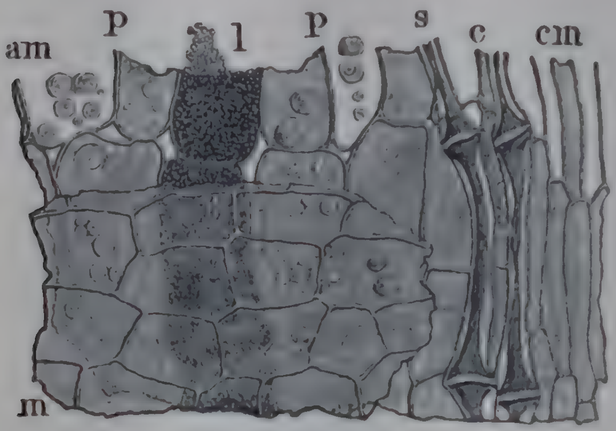

Fig. 27.

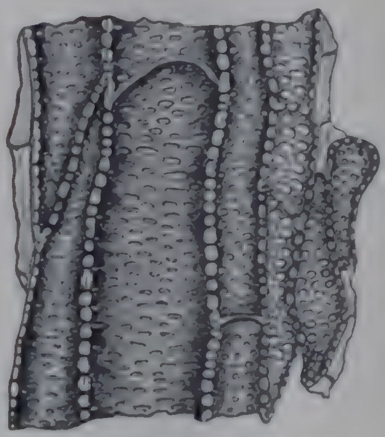

Fig. 28.

Fig. 27.—Sweet Potato. Tuberous root in longitudinal section through cambium and phloem zones. *cm* cambium; *s* sieve tubes; *c* companion cells; *p* starch parenchyma with *am* starch grains; *l* latex cells; *m* medullary cells. × 160. (A.L.W.)

Fig. 28.—Sweet Potato. Vessels of tuberous root in longitudinal section. × 160. (A.L.W.)

The cells of the *medullary rays* (Fig. 27, *m*) are recognized by their radial elongation as seen in longitudinal section.

Cambium (Fig. 25, *Cm*).—The cells form a distinct zone about the root, not interrupted as in the potato. Small chromatophores give them their orange color.

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[1] Comp. Anat. Phan. Ferns, Oxford, 1884, p. 150.

[2] Physiol. Plants, London, 1887, p. 180.

Xylem (Fig. 25, x^1, x^2, x^3; Fig. 28).—The *vessels* are of the pitted type with round or elongated pits seldom large enough to form reticulations. They reach 80 μ in diameter, being largest in the axis of the root. The nature of these vessels and the absence of large spiral or spiral-reticulated cells are evidence that the sweet potato is a tuberous root and not a true tuber.

About many of the vessels (Fig. 25, v^2, v^3), separated from the cambium ring by parenchyma, is a *cobweb tissue* of obviously meristematic cells which may entirely surround the vessel, forming a closed ring, or be lacking on the outside. The fleshy growth appears to be due in considerable part to the activity of these cells, as well as of those of the cambium ring. This peculiar structure, which occurs in other roots (see Rutabaga), is considered at some length by De Bary,[1] who quotes other authors.

The starch grains of the tissues inside the cambium layer are like those outside except that they reach their maximum (50 μ) here. *Latex cells* are also present.

Chief Structural Characters.—Tuberous roots spindle-shaped, white, yellow, red, or purple with white to orange flesh.

Cork cells in strippings quadrilateral in transverse rows. Cortex, phloem, and xylem with starch cells, crystal cells, and latex cells; starch grains of tapioca type, up to 50 μ; vessels pitted, up to 80 μ, often surrounded by meristematic cells forming a cobweb tissue.

CHEMICAL COMPOSITION.—The summary below includes analyses made by chemists at the U. S. Department of Agriculture and at the Connecticut, New York, New Jersey, and South Carolina Experiment Stations prior to 1891 as given in Jenkins and Winton's Compilation,[2] by White,[3] by Failyer and Willard,[4] by Morgan and Ross,[5] by Price,[6] by Jaffa and Curtis,[7] by Agcaoili,[8] and by Adolph.[9] Agcaoili's sample was grown in the Philippines where the vegetable is known as *camote*, Adolph's in China, the Chinese name being *hung-shu.*

Blasdale[10] found on sale in the Chinese Quarter of San Francisco two peculiar varieties of sweet potato, one yellow with angular pointed ends,

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[1] Comp. Anat. Phan. Ferns, Oxford, 1884, p. 606.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11**.

[3] Georgia Agr. Exp. Sta. 1891, Bul. **13**.

[4] Kansas Agr. Exp. Sta. 1891, Bul. **32**.

[5] Louisiana Agr. Exp. Sta. 1892, Bul. **13**, 314.

[6] Texas Agr. Exp. Sta. 1893, Bul. **28**, 329.

[7] California Agr. Exp. Sta. Rep. 1893–4, p. 219.

[8] Philippine J. Sci. 1916, **11**, 91.

[9] Ibid 1926, **30**, 287.

[10] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

COMPOSITION OF SWEET POTATOES

	Samples	Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
		%	%	%	%	%	%	%
Jenkins and Winton:	6							
Min	....	65.96	0.45	0.28	17.98	......	0.60	0.66
Max	....	74.38	3.56	0.60	29.72	......	2.50	1.34
Aver	....	**71.07**	**1.49**	**0.37**	**24.78**	......	**1.27**	**1.02**
White:	5							
Min	....	70.40	1.03	0.22	23.26	2.28*	1.03	0.88
Max	....	73.26	1.90	0.30	25.07	2.62*	1.52	1.22
Aver	....	**71.77**	**1.36**	**0.28**	**24.34**	**2.48***	**1.23**	**1.02**
Failyer and Willard:	2							
Southern Queen	....	69.77	1.78	0.28	26.22	......	0.86	1.09
Red Bermuda	....	71.32	1.89	0.19	24.75	.....	0.74	1.11
Morgan and Ross:	14							
Min	....	58.46	1.00	0.54	25.24	......	0.70	1.01
Max	....	69.45	2.49	1.32	37.12	......	1.09	1.30
Aver	....	**64.32**	**1.67**	**0.80**	**31.18**	......	**0.91**	**1.12**
Price:	21							
Min	....	58.85	0.85	0.55	15.38	2.77†	0.71	0.86
Max	....	79.04	4.37	1.66	34.42	11.90†	1.80	1.58
Jaffa and Curtis:	17							
Min	....	62.94	1.09	0.40	18.41	1.15‡	1.58	0.70
Max	....	75.96	3.42	2.50	43.52	20.86‡	4.54	1.98
Aver	....	**69.00**	**2.08**	**1.00**	**24.23**	**5.55‡**	**2.62**	**1.15**
Agcaoili	....	71.20	0.65	0.52	23.37	......	1.35	0.91
Adolph	....	81.60	1.34	0.05	16.23	......	0.31	0.47

* As sucrose. † Sugar before inversion 2.08 to 5.74%. ‡ Sugar before inversion 0.78 to 5.64, aver. **2.33**%.

resembling a true yam, the other red with rounded ends, the analysis of which follows:

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Yellow	73.44	0.78	0.77	0.25	23.66	4.07	1.71	14.65	1.02	0.85
Red	77.47	0.73	0.70	0.22	19.65	3.19	4.02	9.67	0.93	1.00

Labayen[1] reports analyses of 28 varieties of sweet potatoes grown in the Philippines. The water ranged from 66.08 to 77.09 and the starch from 10.11 to 26.3 per cent.

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[1] Philippine Agr. For. 1914, **3**, 79.

Sweet potatoes grown in South Africa contained, according to Juritz,[1] as follows:

COMPOSITION OF SWEET POTATOES (JURITZ)

	Weight of tuber	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sugars, non-reducing	Fiber	Ash
	g.	%	%	%	%	%	%	%	%
Common 6 mo......	307	70.55	0.94	0.63	26.22	4.47	1.59	0.61	1.05
Red-skinned 3 mo.:									
Whole tuber......	110	80.02	......	......	......	2.68	2.92	......	......
Outer layer.......	......	82.41	0.65	0.42	14.66	......	......	0.68	1.18
Central core......	......	82.49	0.59	0.47	14.97	......	......	0.56	0.92
Yellow-skinned 3 mo.	530	77.06	0.68	0.21	20.42	0.46	2.69	0.80	0.83
White-skinned E. Afr.	470	70.61	1.34	0.46	25.54	5.24	0.81	0.77	1.28

Influence of Fertilizers on Composition.—Schermerhorn[2] secured chunky tubers with high nitrogen but low carbohydrate content by ample fertilization with nitrate nitrogen, and Robbins, Nightingale, Schermerhorn, and Blake[3] demonstrated that an adequate supply of potassium was also essential.

Changes in Composition During Storage.—Three experiments on the carbohydrate transformations and respiratory changes during storage have been carried out by Hasselbring and Hawkins.[4] In the first experiment two varieties were kept in a cellar for about 10 days at the curing temperature of 27° C., after which a part was removed to cold storage at 7.8° C., dropping to 4° C., and the temperature of the cellar was allowed to drop to between 11.7 and 16.7° C., except at the end of the season when it rose to 21.1° C. Selected results are tabulated on the next page.

From the results of the second experiment, the authors conclude that during storage the starch is first converted into reducing sugar and from this in turn sucrose is synthesized.

The third experiment brought out no general correlation between the content of total sugars and intensity of respiration during storage at from 5 to 30° C. Reducing sugars, not sucrose, appear to be consumed during respiration.

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[1] J. Dept. Agr. Union S. Africa 1921, **2**, 340.

[2] New Jersey Agr. Exp. Sta. 1924, Bul. **398**.

[3] New Jersey Agr. 1929, **11**, No. 6.

[4] J. Agr. Res. 1915, **3**, 331, 543; 1915, **5**, 509.

Carbohydrates in Sweet Potatoes During Storage
(Hasselbring and Hawkins)
(Results on water basis at beginning of storage)

	Big Stem				Southern Queen			
	Water	Starch	Dextrose *	Sucrose	Water	Starch	Dextrose *	Sucrose
	%	%	%	%	%	%	%	%
Cellar storage:								
Oct. 20–23	73.50	19.07	0.90	1.90	71.69	22.09	0.39	1.19
Nov. 8–10	72.99	16.94	1.32	3.51	68.41	19.87	0.77	2.97
Dec. 6– 7	71.89	16.42	1.40	3.94	67.69	19.30	0.72	3.50
Jan. 4–11	72.06	16.02	1.28	4.39	67.51	19.75	0.75	3.53
Feb. 1– 3	72.18	14.11	1.67	6.06	68.02	19.22	0.60	3.95
June 1– 4	72.45	14.62	0.87	5.85	68.15	20.15	0.55	2.80
Cold storage:								
Nov. 8–10	72.99	16.94	1.32	3.51	68.41	19.87	0.77	2.97
Dec. 8– 9	72.99	13.31	2.02	6.46	66.77	17.40	0.59	5.93
Dec. 21–22†	70.77	10.80	1.60	7.33	67.57	16.48	0.65	6.94

* Reducing sugar as dextrose. † Tubers rotted soon after.

Freshly dug sweet potatoes in studies by Johnstone[1] showed an increase in respiration from the time of digging, then a gradual decline to a practically uniform rate. The maximum rate in cured sweet potatoes is somewhat lower.

Culpepper and Magoon[2] have studied the composition of 32 varieties of sweet potatoes with reference to canning. Results on the two with the highest and the lowest solids are tabulated on the next page.

Acids.—Viehoever, Kunke, and Mastin[3] found 0.10 per cent of *oxalic acid.*

Carbohydrates.—Examination of sweet potatoes by Miyake[4] showed that the reducing sugars consist of *dextrose* and *levulose* and the nonreducing sugar of *sucrose*; maltose, pentose, galactose, and mannose are absent.

Phosphorus-Organic Compounds.—Ose[5] extracted from commercial dried sweet potatoes, with 96 per cent alcohol at 50 to 60° C., two

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[1] Bot. Gaz. 1925, **80**, 145.

[2] U. S. Dept. Agr. 1922, Bul. **1041**; 1924, Bul. **1265**; J. Agr. Res. 1926, **33**, 627.

[3] Science 1917, **46**, 546.

[4] J. Biol. Chem. 1915, **21**, 503.

[5] J. Agr. Chem. Soc. Japan 1933, **9**, 165.

Composition of Sweet Potatoes Fresh and Cured, Raw and Cooked (Culpepper and Magoon)

	Solids, total	Solids, alcohol-sol.	Solids, alcohol-insol.	Sugars, total*	Sugars, reducing*	Sucrose*	Maltose†	Polysaccharides, total	Dextrin
	%	%	%	%	%	%	%	%	%
Gold Skin									
When dug:									
Raw..........	28.58	5.30	23.28	4.03	1.02	3.01	.....	18.42	.....
Cooked.......	27.87	13.48	14.39	8.92	5.68	3.24	6.14	11.61	0.73
Cured and stored:									
Raw..........	29.06	10.08	18.98	8.09	1.95	6.14	.....	15.18	.....
Cooked.......	30.63	17.40	13.23	12.54	6.14	6.40	5.32	10.58	1.32
Triumph									
When dug:									
Raw..........	38.28	3.98	34.30	2.38	0.28	2.10	.....	27.94	.....
Cooked.......	38.29	19.04	19.25	11.27	9.48	1.79	14.23	16.12	0.98
Cured and stored:									
Raw..........	38.02	7.60	30.42	6.04	0.72	5.32	.....	24.13	.....
Cooked.......	37.84	22.84	15.00	15.53	9.76	5.77	14.02	11.64	1.79

* Calculated as invert. † Increase in sugars after cooking, calculated as maltose.

monoaminophosphatides which may have been of the lecithin and cephalin types.

Phytin.—In the root Bagaoisan[1] found 1.05 per cent, dry basis.

Enzymes.—Gore[2] has shown that the diastatic enzymes of the tuber dissolve nearly all the starch in one and one-half hours at temperatures increasing from 60 to 100° C. He advocates the use of sweet potato flour for mashing and bread making; an addition of 1.5 per cent added to the dough increased the loaf volume nearly 10 per cent.

The *amylase* content of the tubers examined by Giri[3] increased threefold in passing from the skin to the center. It is largely saccharogenic, resembling cereal, but not potato, amylase.

Johnstone[4] states that *catalase*, *laccase*, *peroxidase*, and *amylase* are present, and tyrosinase is absent.

Mineral Constituents.—An analysis of the ash by Jaffa and Curtis[5] follows:

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[1] Philippine Agr. 1932, **21**, 53.

[2] J. Biol. Chem. 1920, **44**, 19; Ind. Eng. Chem. 1923, **15**, 1238.

[3] J. Indian Chem. Soc. 1934, **11**, 339.

[4] Loc. cit.

[5] Loc. cit.

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
58.16	8.12	5.64	4.10	0.54	trace	16.17	2.99	2.14	2.56

Minor Mineral Constituents. *Iron.*—Tuber, peeled 5 mg. per kilo, fresh basis (Sherman).[1] Tuber, 11 samples, 39 to 88, aver. **64** mg. per kilo, dry basis (Remington and Shiver).[2] Tuber 9.2 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Manganese.—Tuber, 9 samples, 2.6 to 17.7, aver. **9.2** mg. per kilo, dry basis (Remington and Shiver).[2]

Copper.—Tuber, 10 samples, 3.4 to 8.8, aver. **6.2** mg. per kilo, dry basis (Remington and Shiver).[2] Tuber 4.1 mg. per kilo (Satterfield and Jones).[4] Tuber 1.5 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[5]

Zinc.—Tuber 2.3 mg. per kilo, fresh basis (Bertrand and Benzon).[6]

[1] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[2] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Elisha Mitchell Sci. Soc. 1932, **48**, 16.

[5] J. Biol. Chem. 1929, **82**, 465.

[6] Bul. soc. hyg. aliment. 1928, **16**, 457.

ROOTS OF THE BELLFLOWER FAMILY

(*Campanulaceæ*)

RAMPION is the only available species of this family yielding an edible root.

Latex tubes of the chicory type and *vessels* of the carrot type are the conspicuous elements.

RAMPION

Campanula Rapunculus L. = *Rapunculus verus* Fourr.

Fr. Raiponce. Sp. Cardenala.—It. Raperonzolo. Ger. Rapunzelrübe.

The genus *Campanula* is represented by this lesser-known salad plant of which both the root and the leaf are used. See section on Leaf Vegetables.

MACROSCOPIC STRUCTURE.—The *root* resembles a long white radish. The cork, cortex, and phloem form a very thin layer about 0.5 mm. thick in a root 1.5 cm. in diameter.

MICROSCOPIC STRUCTURE.—Cork Cells form several tiers. In tangential section the cells are transversely elongated.

Cortex.—The *ground parenchyma*, as in the phloem and xylem, consists of longitudinally elongated cells in radial rows best seen in radial longitudinal section. The numerous *latex tubes*, of the same type as in chicory, branch and anastomose.

Phloem.—*Latex tubes* also run through the phloem.

Xylem.—The *vessels* resemble those of the carrot. They range up to 50 μ wide. The reticulated forms often show in longitudinal section two or three rows of diamond-shaped reticulations formed by narrow bars meeting broad ones. Spiral vessels also are present.

Although under a lens cross sections show radiating bands, under the microscope there are no sharply defined medullary rays.

CHIEF STRUCTURAL CHARACTERS.—Root similar to white radish; cambium layer near surface.

Cortex and phloem with branching and anastomosing latex tubes. Vessels up to 50 μ, often reticulated with diamond-shaped meshes.

ROOTS OF THE COMPOSITE FAMILY

(*Compositæ*)

THREE root vegetables belong to the *Cichoriaceæ* tribe (*Liguliforæ*) as follows: common salsify (*Tragopogon porrifolius* L.), scolymus or Spanish salsify (*Scolymus hispanicus* L.), and scorzonera or black salsify (*Scorzonera hispanica* L.). Of these, common salsify is the best known; the other two are not listed by most American seedsmen. Great burdock (*Arctium Lappa* L.), a cultivated form of burdock belonging to the *Cynaroideæ* tribe, is an important root vegetable in Japan.

Chicory root (*Cichorium Intybus* L.), used for coloring and flavoring coffee, and dandelion root (*Taraxacum officinale* Weber), an alleged adulterant of chicory, are described in Volume III.

COMPARATIVE MACROSCOPIC STRUCTURE.—Particularly prominent is the neck or fleshy stem with leaf scars. The *root* proper is characterized by the milky juice of the cortex and phloem.

COMPARATIVE MICROSCOPIC STRUCTURE.—*Inulin*, contained chiefly in the parenchyma outside of the cambium ring, and *latex*, contained in branching and anastomosing tubes accompanying the sieve tubes, are the characteristic constitutents.

COMPARATIVE CHEMICAL COMPOSITION.—The literature is exceedingly limited. The group offers a rich field for investigation.

SALSIFY

Tragopogon porrifolius L.

Fr. Salsifis. Sp. Ostion vegetal. It. Sassefrica. Ger. Haferwurzel.

Two common species belong to the genus *Tragopogon*, salsify or oyster plant, perhaps the most valuable root vegetable of the family, and goat's beard or Johnny-go-to-bed-at-noon (*T. pratensis* L.), a common weed, the former being purple-flowered, the latter yellow-flowered. Both are natives of Europe and other parts of the Old World.

Salsify, because of its oyster-like flavor, is much prized in regions remote from the salt water. This flavor is not, however, confined to this vegetable but is marked in roots of other composite plants, as well as the receptacle of the artichoke, all of which contain inulin and latex.

MACROSCOPIC STRUCTURE.—The *root*, which seldom exceeds 4 cm. in diameter, resembles a small parsnip but has a broader and longer crown forming a kind of neck with bases or scars of the strap-shaped leaves. Small rootlets spring from transverse markings on the surface of the root proper. On cutting, an abundance of milky latex exudes which becomes chocolate brown on drying. The phloem rays also become brown on drying, while the xylem becomes yellow.

MICROSCOPIC STRUCTURE (Fig. 29).—Salsify differs from chicory, which it resembles in general structure, in that the vessels are narrower and not so numerous, and wood fibers are absent or not noticeable.

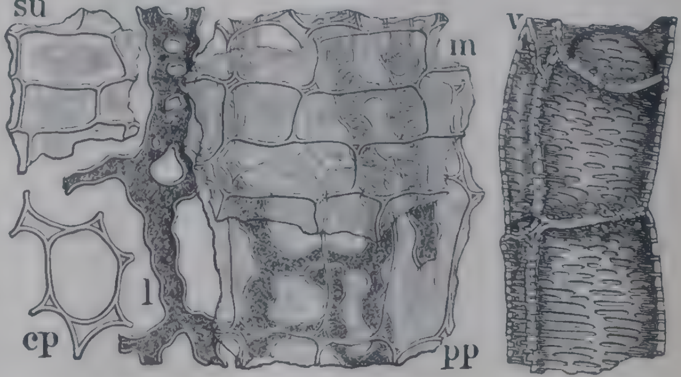

Fig. 29.—Salsify. Elements of root. *su* cork in surface view. The following in longitudinal section: *cp* round cells of cortex with intercellular spaces; *l* latex tubes and *pp* parenchyma of phloem; *m* cells of medullary rays separating phloem rays; *v* vessels showing extremes of breadth. ×160. (A.L.W.)

Cork (*su*).—The cells are several thick, small, in surface view more or less rectangular and transversely elongated.

Cortex.—This is thin, consisting usually of only five or six cell rows. In cross section the cells are similar to the cork cells in shape, but they are larger and show a greater tendency to break joints. In longitudinal section (*cp*) they are distinguished by their greater breadth, rounded form, and intercellular spaces.

The *endoderm*, forming a boundary between the cortex and the phloem, may often be identified in cross or longitudinal sections of roots of moderate size after staining with safranin and removing the excess of stain with alcohol. The suberized portion of the radial walls, being deeply stained, contrasts strongly with the other walls that take on a lighter color.

Phloem.—Cross sections show the thin-walled, isodiametric, rounded cells of the ground parenchyma, also the radial, more or less interrupted strings of sieve tubes, companion cells, and latex tubes. The medullary cells are not sharply defined.

Longitudinal sections show the transition of rounded to rectangular, longitudinally elongated cells of the *ground parenchyma* (*pp*), arranged side by side in radial rows, and the rectangular, radially elongated cells of the *medullary rays* (*m*), further distinguished from the cells of the ground parenchyma by their muriform arrangement.

Inulin, the chief cell constituent, is not shown in the figure but, as in chicory and other composite roots, forms sphæro-crystals in alcoholic specimens.

Sieve tubes (not shown) are distinguished from the latex tubes both by the absence of granular contents and the presence of sieve plates. The *latex tubes* (*l*) are striking elements in longitudinal sections. They branch and anastomose, forming a network conspicuous because of the finely granular latex. Blind ends, also small rounded intercellular spaces formed between points of contact of two adjacent tubes, are evident.

Cambium.—Composed of typical small cells.

Xylem.—The *xylem parenchyma* is not noticeably different from the phloem parenchyma. Cross sections do not bring out clearly the medullary rays, but longitudinal sections show that the cells are radially elongated as in the phloem. The *vessels* (*v*) belong more to the pitted than the reticulated class, with very narrow transversely elongated pits. They vary greatly in width (up to 80 μ), seldom if ever reaching the breadth of the vessels of chicory. In the stem tissues of the neck are large spiral vessels running into the leaves. Because of the smaller and less numerous vessels, the xylem is not so tough and woody as that of chicory.

Chief Structural Characters.—Root slender with broad, short crown; latex brown on exposure to air.

Cork cells rectangular, transversely elongated; cortex cells transversely elongated, larger than cork cells, rounded in longitudinal section. Endoderm present. Phloem parenchyma of rectangular, longitudinally elongated cells in radial rows; Medullary cells radially elongated in radial rows. Inulin abundant throughout phloem zone. Latex tubes branching and anastomosing, accompanying sieve tubes. Vessels up to 80 μ, mostly pitted, with transversely elongated pits; vessels in crown spiral.

CHEMICAL COMPOSITION.—No proximate analysis or ash analysis available.

Carbohydrates.—See *Inulin* under Jerusalem Artichoke.

Minor Mineral Constituents. *Iron.*—Root 12.4 mg. per kilo, fresh basis (Peterson and Elvehjem).[1]

Aluminum.—Root 56 mg. per kilo, dry basis (Bertrand and Lévy).[2]

Manganese.—Root 12.4 mg. per kilo, dry basis (Peterson and Skinner).[3]

Copper.—Root, fresh 3.2, dry basis 22.6 mg. per kilo (Guérithault).[4] Root 2.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[5]

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[1] J. Biol. Chem. 1928, **78**, 215.

[2] Compt. rend. 1931, **192**, 525.

[3] J. Nutrition 1931, **4**, 419.

[4] Compt. rend. 1920, **171**, 196.

[5] J. Biol. Chem. 1929, **82**, 465.

Zinc.—Root 2.2 mg. per kilo, fresh basis (Bertrand and Benzon).[1]
Arsenic.—Root 0.11 mg. per kilo, fresh basis (Jadin and Astruc).[2]

SCOLYMUS

Scolymus hispanicus L.

Fr. Cardon d'espagne. Ger. Spanische Golddistel.

Spanish salsify, golden thistle, and Spanish oyster plant are names sometimes used for this biennial root vegetable. It is seldom listed by American seedsmen but is claimed to be superior to ordinary salsify in that the root is larger and better flavored.

MACROSCOPIC STRUCTURE.—The root leaves are spiny; the flowers are yellow, thistle-like. Grown from seed, the *root* at the end of the first year is light colored, tapering, resembling a small parsnip. Eaten boiled, it has a pronounced oyster flavor. In cross section, little if any latex exudes, although latex tubes are present in abundance.

MICROSCOPIC STRUCTURE.—The *latex tubes* branch and anastomose as in salsify. Both the phloem and xylem parenchyma consist of longitudinally elongated, rectangular cells in radial rows, containing much *inulin*. De Bary,[3] on the authority of Van Tieghem, states that oil passages (ducts) occur only in the root of *S. grandiflorus* among the *Cichoriaceæ*. Such were not noted in the root of *S. hispanicus* grown and examined by the authors.

The *vessels* are not numerous. They reach 60 μ or over and have long, narrow pits extending well across the surface. Forms approaching spiral vessels are numerous.

CHIEF STRUCTURAL CHARACTERS.—Root light colored, resembling small parsnip.

Structure similar to salsify but vessels with longer pits.

CHEMICAL COMPOSITION.—No proximate analysis is available.

Carbohydrates.—See *inulin* under Jerusalem Artichoke.

SCORZONERA

Scorzonera hispanica L.

Fr. Scorsonère. Sp. Escorzonera. It. Scorzonera. Ger. Schwarzwurzel.

Black salsify is a common name for this vegetable.

MACROSCOPIC STRUCTURE.—The *flowers* are yellow, subtended by a several-rowed involucre. The surface of the *root* becomes black when of edible size.

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[1] Bul. soc. hyg. aliment. 1928, **16**, 457.

[2] Compt. rend. 1912, **155**, 291.

[3] Comp. Anat. Phan. Ferns, Oxford, 1884, p. 448.

MICROSCOPIC STRUCTURE.—Resembles common salsify except that the *cork cells* of the root are black, owing evidently to humification.

CHEMICAL COMPOSITION.—Dahlen[1] found in roots harvested in December:

Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
%	%	%	%	%	%	%
80.39	1.04	0.50	14.80	2.19	2.27	0.99

Carbohydrates.—See *inulin* under Jerusalem Artichoke.

GREAT BURDOCK

Arctium Lappa L.

Chin. Ngau-pong. Jap. Gobo.

Burdock, known in the Occident only as an unsightly weed, has been so bred in Japan as to furnish a root vegetable which, according to Kondo,[2] is of great importance. For some years the writers have grown this vegetable from seed furnished by Dr. Kondo.

Although commonly stated to be a biennial, with us it appears to be a triennial, ripening seed the second and third years. If the soil is stony or not deeply worked, the roots tend to branch, with consequent injury to the crop. In many cases the roots grow to such a depth as to render digging difficult and at best not complete.

MACROSCOPIC STRUCTURE.—The *flowers* resemble small thistles, being much larger in the cultivated form than in the weed. The *root-leaves*—the only ones to appear the first year—are large with long petioles, resembling in form and size those of garden rhubarb, but they have a felt of hairs beneath.

Properly grown, the *root* resembles salsify but is thicker (often 4 cm.) and longer (up to 1 meter). It is rough, dark brown when full grown, with transverse wrinkles and numerous small branches. Cut transversely, latex exudes from the phloem zone which is of a green-gray color, contrasting with the nearly white cortex and the cream-colored or pink xylem zone. In edible roots, the cambium zone is from one-third to one-fifth the distance from periphery to center. Large roots are often hollow.

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[1] Landw. Jahrb. 1875, **4**, 613.

[2] Über die in der Landw. Japans gebrauchten Samen. B. Ohara Inst. landw. Forsch. 1919, **1**, 428.

MICROSCOPIC STRUCTURE.—Compared with salsify, the bundle rays are separated by broader medullary rays, while the vessels are less numerous although somewhat larger, reaching 110 μ in the center of the root.

Chief Structural Characters.—Root thicker and larger than salsify root and with larger vessels (110 μ) but otherwise similar in structure.

CHEMICAL COMPOSITION.—An analysis made in China by Sherman and Wang[1] and one made in Hawaii by Chung and Ripperton[2] follow:

Composition of Great Burdock Root

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Sherman and Wang......	76.96	2.24	0.11	18.13	1.51	0.87
Chung and Ripperton....	60.62	1.09	0.07	33.37	3.78	1.07

Carbohydrates.—No quantitative data on the content of *inulin* and other carbohydrates are available. See inulin under Jerusalem Artichoke.

Mineral Constituents.—Chung and Ripperton[3] report calcium 0.064, phosphorus 0.039, and iron 0.0039 per cent of the fresh material.

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[1] Philippine J. Sci. 1929, **38**, 69.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[3] Loc. cit.

TUBER, CORM, AND RHIZOME VEGETABLES

(Subterranean Stems)

VARIOUS modifications of stems, growing completely or partly underground, serve as storehouses for reserve material during the resting season. Aerial stems of certain perennial plants, such as the sago palm, also serve as reservoirs for starch during the resting season, showing that such a deposition is not a fundamental peculiarity of subterranean modifications, but the succulent aerial stems and leaf parts of annual plants do not have such accumulation.

MACROSCOPIC STRUCTURE.—*Tubers* are enlargements of slender subterranean stems with leaves represented by minute scales subtending shoot buds.

Corms are short, more or less erect, thickened subterranean stems with leaves reduced to small scales.

Rhizomes, or root stocks, are prostrate, wholly or partially buried, with terminal shoot bud and scars of leaves of preceding years.

Further characteristics of subterranean stems are described under the different family groups.

MICROSCOPIC STRUCTURE.—The general structure of aerial stems is modified in subterranean stems because of their different function and their location: (1) they are fleshy, the bulky parenchymatous cells being filled with reserve material in the form of starch, inulin, or other carbohydrate; (2) they do not contain chlorophyl in considerable amount.

Although garden roots are all of dicotyledonous plants, subterranean stems are partly of dicotyledonous (potato, Jerusalem artichoke, lotus) and partly of monocotyledonous (water chestnut, chufu, taro, yam). Both types have an outer tissue consisting of a simple *epiderm*, or several layers of *cork cells*, and a *cortex* with or without a well-developed inner cell layer, the *endoderm*. The *central cylinder* in the dicotyledonous group consists of concentric rings of phloem, cambium, and xylem tissues about a central pith, whereas the central cylinder of the monocotyledonous group consists of a parenchymatous ground tissue through which run scattered fibro-vascular bundles. A zone of *stone cells* (pericycle) occurs inside of the cortex of the yam.

In both groups the carbohydrate reserve material occurs throughout the parenchyma of cortex and central cylinder. The *starch grains* differ greatly in form and size. See Figs. 1, 6, 8, 22, 23, 34, and 36, Volume I. *Raphides* occur in taro and other aroids, also in the different species of yam.

TUBERS OF THE WATER PLANTAIN FAMILY

(*Alismaceæ*)

THE starchy tubers of the arrowheads are classified under this head. In addition to *starch grains*, the *chains of cells* in the outer cortex and the canals in the central cylinder are noteworthy.

ARROWHEAD

Sagittaria spp.

Fr. Sagittaire. It. Quadrello. Ger. Pfeilkraut. Chin. Chee-koo.
Jap. Kuwai.

Tubers, or more correctly tuberous rhizomes, of the arrowhead of the Old World (*S. sagittifolia* L. or a variety known as *S. chinensis*) imported from China and of the American species (*S. latifolia* Willd. = *S. variabilis* Engelm.) are used by the Chinese in the United States as a vegetable. The latter species, according to the various authors quoted by Blasdale,[1] furnishes the American Indians with a palatable food. In China, starch is made from the tubers.

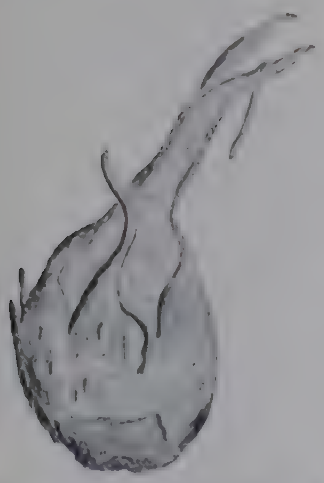

FIG. 30. — Arrowhead. Corm. ×½. (A.L.W.)

MACROSCOPIC STRUCTURE.— As illustrated by Blasdale, the tubers of the Chinese species are nearly round, while those of the American species (Fig. 30) are ovoid, both being extended into an elongated sprout and encircled by two or more leaf scars with scales. The flesh is creamy white, somewhat spongy in texture.

MICROSCOPIC STRUCTURE.—The American species has the following structure:

Epiderm.—Tangential sections show that the cells have yellow walls and are more or less quadrilateral, longitudinally elongated, and arranged in longitudinal rows.

Cortex.—In cross section, the cells of the outer part appear to form chains about large intercellular spaces; farther inward they form a close tissue with no evident separation from the central cylinder. The *starch grains* increase in size inward.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

Central Cylinder.—The *starch grains*, which appear to be identical in the two species, are spherical, oval, triangular, or irregular with central hilum, and vary up to 36 μ in their longer diameter. See Commercial Starches, Volume I.

Scattered through the ground tissue are branching *canals* and *fibro-vascular bundles* with narrow vessels. The canals are surrounded by smaller cells which as seen in cross section project in a series of curves into the lumen and as seen in longitudinal sections contain small starch grains, mostly 3 to 5 μ in diameter. Contents in the canals, if present, are not abundant.

Chief Structural Characters.—Tubers spherical (Chinese) or ovoid (American) with rings of leaf scars and a sprout at the end.

Epiderm of elongated yellow-walled cells. Outer cortex of rounded starch cells about large intercellular spaces, passing into the close tissue of the central cylinder. Starch grains spherical, oval, triangular, etc., up to 36 μ, with central hilum. Central cylinder characterized by canals, surrounded by cells with small starch grains and by the narrow vessels of the fibro-vascular bundles.

CHEMICAL COMPOSITION.—Analyses by Blasdale,[1] Sherman and Wang,[2] and Chung and Ripperton[3] are included in the following table:

Composition of Arrowhead Tubers

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Blasdale:									
S. latifolia . .	66.88	4.44	3.98	0.76	24.90	2.49	19.69	0.98	2.04
S. sinensis . .	61.51	7.00	4.71	0.24	28.84*	2.26	22.95	0.72	1.69
S. and W.:									
S. sagittifolia	74.54	5.17	....	0.15	18.11	......	......	0.63	1.40
C. and R.:									
S. sagittifolia	76.46	4.71	....	0.37	16.12	......	......	0.67	1.67

* Pentosans 0.32%.

Nitrites, according to Aso and Sekine,[4] occur in the shoot-like buds, owing perhaps to the oxidation of amino acids or the reduction of nitrates.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Philippine J. Sci. 1929, **38**, 69.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[4] Bot. Centralb. 1914, **32**, 146.

Carbohydrates.—Miyake[1] in arrowhead tubers (*Sagittaria sagittifolia forma sinensis*) demonstrated the presence of *dextrose*, *levulose*, *galactose*, and *sucrose* and isolated what appeared to be *raffinose*. Galactose may have been combined with other sugars. Maltose, pentose, and mannose were not found.

Mineral Constituents.—Chung and Ripperton[3] found in the fresh material: calcium 0.016, phosphorus 0.207, and iron 0.0049 per cent.

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[1] J. Biol. Chem. 1913, **15**, 221.

[2] Loc. cit.

CORMS AND TUBERS OF THE SEDGE FAMILY

(*Cyperaceæ*)

THE water chestnut (*Eleocharis tuberosa* Schult.) of the Orient yields an edible corm; the chufa (*Cyperus esculentus* L.) of the Occident yields an edible tuber.

COMPARATIVE MACROSCOPIC STRUCTURE.—The water chestnut is onion-shaped; the chufa, ovoid. Both have transverse rings formed by leaf scars. In the water chestnut the central cylinder begins near the surface; in the chufa about two-thirds the distance to the center.

COMPARATIVE MICROSCOPIC STRUCTURE.—The *epidermal cells* of the water chestnut are longitudinally elongated; of the chufa, transversely elongated. In both species cork is absent; in the chufa a hypoderm made up of stone cells and sclerenchyma fibers is present.

The *starch grains* of the water chestnut are commonly three-, four-, or five-sided, up to 27 μ in diameter; those of the chufa are commonly pear-, kidney-, or spindle-shaped, up to 18 μ in diameter. The *vessels* are somewhat broader (up to 30 μ) in the water chestnut than in the chufa (up to 20 μ).

COMPARATIVE CHEMICAL COMPOSITION.—Chufas differ markedly from water chestnuts in being rich in *oil*. Oil in a subterranean stem used as food is unusual. *Starch* and *sugars* are present in both.

WATER CHESTNUT

Eleocharis tuberosa Schult.

Those frequenting the Chinese restaurants of American cities are familiar with the peculiarly crisp and sweet water chestnut; others would do well to test its merits. The English name, stated by Blasdale[1] to be a free translation of *ti leh*, is a misnomer since it is a corm of a sedge that grows wild in wet places; *ma hai* is another name. Adolph[2] gives *p'o-ch'i*. The corms are eaten raw and are also a source of commercial starch.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Philippine J. Sci. 1926, **30**, 287.

Eleocharis dulcis (Burm. f.) Trin., known in the Philippines as *apulio,* is grown as a food plant by the natives. *Scirpus tuberosus* is grown in both China[1] and Japan, the corms being eaten raw and boiled. Chung and Ripperton[2] give *ma-tai* as the Chinese and *kuro-kuwai* as the Japanese name.

MACROSCOPIC STRUCTURE.—As found on sale in the Chinese Quarters of New York, the *corm* (Fig. 31) is dark brown, onion-shaped, 2 to 4 cm. broad, with the remains of the leaf bases at the top and a circle of leaf scars about the middle. Cut transversely, the flesh is whitish with a narrow line (endoderm) about 1 mm. from the surface.

MICROSCOPIC STRUCTURE.—In place of the typical cork of roots and tubers, a single epidermal layer and a hypoderm, several cells thick, are present, both being of a brown color.

Epiderm.—The cells are narrow (10 to 20 μ), somewhat longitudinally elongated, with distinctly porous walls up to 5 μ thick.

Hypoderm.—Proceeding inward, the cells increase in size but diminish in color and in the thickness of the walls, which in the outer row of cells is often 10 μ. Round pores are distinctly evident.

Cortex.—In the outer part, the *parenchyma cells* are isodiametric without marked intercellular spaces; in the inner part, they form a spongy parenchyma with star-shaped arms. *Starch grains,* like those of the central cylinder, are conspicuous. Here and there occur longitudinally elongated *oleoresin sacs* of a brown color.

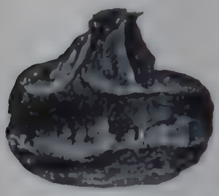

FIG. 31.—Water Chestnut. Corm. × ½. (A.L.W.)

The cells of the *endoderm* are noticeable because of their brown walls.[3] As seen in cross section, the inner and radial walls are noticeably thickened. In longitudinal section, they are elongated but with only slightly wavy walls.

Central Cylinder.—The *pericycle* is not noticeably differentiated at the mature stage. The *ground parenchyma* differs from the parenchyma of the cortex in that the cells are larger; the *starch grains* are also larger, reaching 27 μ, the larger grains being triangular, quadrilateral, pentagonal, spindle-shaped, and of other curious forms. A small central hilum, but usually no rings, is evident, and polarization phenomena are not well marked. See Commercial Starches, Volume I. *Fibro-vascular bundles* occur at intervals in the ground parenchyma. The *vessels,* which partly surround the phloem, are scalariform or pitted, up to 30 μ broad, or else spiral or spiral-reticulated and narrow. *Bast fibers* are not present, although the parenchyma about the bundles may be of somewhat elongated elements.

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[1] Bretschneider: J. China Branch Roy. Asiatic Soc. 1890–1, **25**, 47.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[3] De Bary: Comp. Anat. Phan. Ferns, Oxford, 1884, pp. 122, 124.

Chief Structural Characters.—Corm onion-shaped, 2 to 4 cm. broad, brown, with dried leaf bases and ring of leaf scars; flesh whitish. Cortex about 1 mm. thick.

Epiderm of brown, elongated, porous cells; hypoderm of similar cells but larger and thicker-walled. Cortex with brown secretion cells in ground tissue of starch parenchyma. Endoderm distinct, brown. Starch grains of central cylinder up to 27 μ, often three-, four-, and five-sided. Vessels scalariform up to 30 μ broad, narrow spiral, or spiral-reticulated.

CHEMICAL COMPOSITION.—Following are analyses of water chestnut by Blasdale,[1] by Sherman and Wang,[2] and by Adolph,[3] designated *Eleocharis tuberosa*; by Hemmi,[4] designated *E. plantaginea*; and by Chung and Ripperton,[5] designated *Scirpus tuberosus*:

Composition of Water Chestnut

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Blasdale:										
I......	77.29	1.53	1.16	0.15	18.90	1.94	6.35	7.34	0.94	1.19
II......	77.89	1.31	1.00	0.27	18.13	2.60	6.02	8.09	1.22	1.18
Hemmi...	68.52	2.25	1.69	0.19	26.46*	0.24	1.06†	18.75	1.00	1.58
S. and W.	71.19	1.63	....	0.13	24.63	......	......	......	1.24	1.18
C. and R.‡	79.54	5.89	....	0.04	13.07	......	......	......	0.55	0.91
Adolph ‡.	79.20	1.84	....	0.18	17.12	......	......	......	0.70	0.96

* Dextrin 0.60%, pentosans 0.79%. † Non-reducing sugar. ‡ Peeled.

Hemmi found that the hemicellulose of the corms yielded on hydrolysis *l*-arabinose.

Adriano, Manahan, and Barros,[6] under the head of roots and tubers, give an analysis of apulio (*E. dulcis* (Burm. f.) Trin.) as follows: water 61.34, protein 0.32, fat 0.15, nitrogen-free extract 35.48, fiber 1.48, and ash 1.23 per cent. The low water and protein content indicates that the product is not similar to the water chestnuts described above.

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[1] Loc. cit.

[2] Philippine J. Sci. 1929, **38**, 69.

[3] Loc. cit.

[4] J. Col. Agr. Hokkaido Imp. Univ. 1918, **8**, 33.

[5] Loc. cit.

[6] Philippine Agr. 1929, **18**, 119.

The edible stem of *Eleocharis plantaginea* R. Br., known as *be-chi*, used as a food in Formosa, contains according to Okumura;[1] water 86.85, protein 1.41, fat 0.22, nitrogen-free extract 9.60, reducing sugars 1.45, non-reducing sugars 0.81, starch 5.00, fiber 0.98, and ash 0.94 per cent.

From the air-dry material, adenine, trigonelline, and choline were isolated.

Mineral Constituents.—Chung and Ripperton[2] report the following figures in percentages of the peeled corms: calcium 0.002, phosphorus 0.065, and iron 0.0018 per cent.

CHUFA

Cyperus esculentus L. = *C. phymatodes* Muhl.

Fr. Souchet comestible. Ger. Erdmandel.

Gray gives the range of this plant from New Brunswick to Florida and west to Minnesota and Texas. Although regarded as a bad weed, it is nevertheless grown extensively in the South and occasionally in the North for the tubers, which, in their crispness and nutty flavor, resemble water chestnuts. They are also roasted for use as a coffee substitute. As a food for swine—who do their own harvesting—chufas are much prized in the southern states.

MACROSCOPIC STRUCTURE.—The *tubers* are brown, 1 to 2 cm. long, about half as broad, and have two or three circular markings formed by leaf scars on the surface. When they are cut transversely, a distinct brown circle, two-thirds of the distance from the surface to the center, is seen to separate the cortex from the central cylinder.

MICROSCOPIC STRUCTURE.—Sections are soaked in ether to remove the oil which otherwise would obscure the starch and cell walls.

Epiderm.—In surface view the cells are more or less transversely elongated, often side by side in longitudinal rows, forming a single brown layer. The walls are yellow-brown, somewhat thickened, and porous.

Hypoderm.—The first row of cells is of typical *stone cells* with thick walls and narrow lumen; the remaining rows (about three or four) are of longitudinally arranged *sclerenchyma fibers*, the lumen increasing in size in each successive row, passing into the ground tissue of the cortex. As in the epiderm, the walls are yellow-brown.

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[1] J. Tokyo Chem. Soc. 1920, **41**, 556.

[2] Loc. cit.

Cortex.—The cells of the ground tissue are isodiametric with somewhat thickened walls (3 to 5 μ) pierced by distinct rounded pores. The *starch grains* are like those of the central cylinder.

Between the ground tissues of the cortex and the central cylinder are two rows of cells distinguished by their yellow-brown walls and, as seen in cross section, by their more or less quadrilateral form and short radial diameter. The outer row is *endoderm.*

Central Cylinder.—The *pericycle* consists of the row of cells within the endoderm. Porous-walled parenchyma cells, like those of the cortex, form the *ground tissue* through which run the bundles. The *starch grains* range up to 18 μ in length, pear-shaped, kidney-shaped, and spindle-shaped forms being noticeable. Neither hilum nor rings are distinct. Polarization crosses are distinct but not brilliant. The *fibro-vascular bundles* are neither numerous nor conspicuous. The *vessels* are narrow (up to 20 μ), spiral-reticulated forms predominating. Bast fibers are not evident.

CHIEF STRUCTURAL CHARACTERS.—Tubers longer than broad, marked by leaf scar rings, oily. Diameter of central cylinder one-third of the whole.

Epidermal cells transversely elongated, side by side in longitudinal rows. Hypoderm of sclerenchyma cells and fibers, several thick. Cortex and ground tissue of central cylinder of porous cells containing starch. Starch grains up to 18 μ, pear-shaped, kidney-shaped, spindle-shaped, etc. Endoderm and pericycle of brown quadrilateral cells. Vessels narrow (up to 20 μ), spiral-reticulated forms predominating.

CHEMICAL COMPOSITION.—Luna[1] found in chufas: fat 28 per cent, of which 17 per cent was obtained by pressing and 11 per cent by subsequent extraction, sucrose 14 per cent, starch 29 per cent, and small amounts of protein and other constituents.

Power and Chesnut[2] found: oil (petroleum ether extract) 28.9 and starch 12.8 per cent. They were able to demonstrate the presence of sucrose by crystallization, notwithstanding the presence of interfering albuminous and gummy substances. No alkaloid, asparagine, or caffeine could be detected. Pieraerts[3] reports oil 20 to 27, sucrose 15 to 20, and starch 25 to 30 per cent. Ruitikov[4] also gives results on these constituents.

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[1] J. pharm. chim. 1851 [3], **19**, 336.

[2] J. Agr. Res. 1923, **26**, 69.

[3] Mat. grasses 1924, **16**, 6674.

[4] Schrift. zentr. Forschungsinst. Lebensmittelchem. (U.S.S.R.) 1933, **4**, 136.

Volatile Oil.—From the root (rhizome?) of *C. rotundus* L. grown in Japan, Kimura and Ohtani[1] obtained by steam distillation about 1 per cent of an essential oil consisting of 32 per cent of cyperene ($C_{15}H_{24}$), boiling at 110 to 115° (7 mm.), and 49 per cent of cyperol ($C_{15}H_{24}O$), boiling at 147 to 150° (8 mm.). By catalytic reduction, dihydrocyperene ($C_{15}H_{26}$) was prepared from the former and dihydrocyperol ($C_{15}H_{26}O$) from the latter.

Fatty Oil.—Baughman and Jamieson[2] determined the values of the oil extracted by Power and Chesnut, and Pieraerts[3] of a sample of expressed oil of his own preparation.

Values of Chufa Oil

	Sp. gr. 15° C.	Ref. index 25° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Acetyl No.	Acid No.
B. and J.	0.918	1.4662	191.5	76.50	0.2	0.3	10.5	15.70
Pieraerts	0.918	1.4650	191.3	76.89	0.2	....	4.55*	1.70

* André method.

In addition to the above figures, Baughman and Jamieson found saturated acids, observed 18.3 (iodine number 6.5), corrected 17.1; unsaturated acids, observed 74.6 (iodine number 96.9), corrected 75.8; Pieraerts determined the values of the insoluble fatty acids including soldifying point, which was 21° C. (superfused).

Composition.—The following calculated figures by Baughman and Jamieson are based on their analytical data:

	%
Glycerides of:	
Lignoceric acid	0.3
Arachidic acid	0.5
Stearic acid	5.2
Palmitic acid	11.8
Myristic acid	trace
Oleic acid	73.3
Linolic acid	5.9
Unsaponifiable matter	3.0
	100.0

Pieraerts, contrary to the findings of Baughman and Jamieson, states that the solid acids consist chiefly of myristic acid with a small amount of palmitic acid.

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[1] J. Pharm. Soc. Japan 1928, **48**, 971.

[2] J. Agr. Res. 1923, **26**, 77.

[3] Loc. cit.

Phytosterol.—In the unsaponifiable matter, Baughman and Jamieson found a phytosterol melting at 134 to 135° C.

Enzymes.—Bustinza y Lachiondo[1] showed the presence of *oxidase*, *peroxidase*, *catalase*, *philothion*, *lipase*, *glycerophosphatase*, *invertase*, and *amylase*, but no emulsin.

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[1] Rev. acad. cienc. Madrid 1929, **24**, 411.

CORMS, SHOOTS, AND PETIOLES OF THE ARUM FAMILY

(*Araceæ*)

THIS family, to which belong the calla lily, the Jack-in-the-pulpit, and various ornamentals, is represented among food plants chiefly by three genera (*Colocasia*, *Xanthosoma*, and *Alocasia*) yielding starchy corms and cormels of great importance in the tropics.

The taros, including taniers (tanyahs) and dasheens, belong to the genus *Colocasia* (*C. antiquorum* Schott. and *C. esculentum* (L.) Schott.); the yautias and eddos belong to the genus *Xanthosoma*, the general name of yautia applying to the group. Species of *Alocasia* are of less importance, corms of most varieties being inedible. The U. S. Department of Agriculture through the Office of Plant Introduction has carried out extensive investigations[1] with taros, dasheens, and yautias and has introduced promising species into the United States.

Species of *Arum* yield corms as yet of subordinate importance. The corms of *Amorphophallus Rivieri* Dur. and its variety *Konjac* Engler (*Conophallus Konjac* Koch) are used for food in China and Japan. Blasdale[2] found the former on sale in the Chinese Quarters in San Francisco.

COMPARATIVE MACROSCOPIC STRUCTURE.—The spherical or ovoid *corms* and *cormels* are covered with concentric rings, due to leaf scars, and shaggy scales. Scattered through the flesh are numerous bundles.

COMPARATIVE MICROSCOPIC STRUCTURE.—The principal tissues are *cork* in many tiers, *cortex* and *ground parenchyma* with small starch grains, *fibro-vascular bundles* with xylem of mostly spiral and spiral-reticulated vessels partly enclosing the phloem, and *latex tubes*, the contents of which change to a brown color. *Raphides cells* may or may not be present, their presence being an indication of acridity.

Taros and yautias differ in structure chiefly in the size of the starch grains, which are larger in the latter.

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[1] Barrett: U. S. Dept. Agr., Bur. Plant Ind. 1910, Bul. **164**. Young: U. S. Dept. Agr. 1924, Farm. Bul. **1396**; U. S. Dept. Agr. 1924, Dept. Bul. **1247**.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

COMPARATIVE CHEMICAL COMPOSITION.—*Starch* is the chief constituent in all the members of the group. The literature is largely limited to proximate and partial ash analyses.

TARO

Colocasia spp. = *Arum esculentum* L.

Fr. Arum colocasie. Ger. Taro. Chin. Bun-long-woo.

Under this head are included the corms and cormels of the taros and the type known as dasheen (a corruption of *de chine*) which is the most important in the United States, also the taniers. The nomenclature of the group is much confused. R. A. Young[1] groups under *C. antiquorum* Schott., Egyptian or red taro, represented in the United States by the blue tanier and common elephant's ear or " caladium " of the flower garden, and under *C. esculentum* (L.) Schott., Penang taro and dasheens, the classification being based on characters of the plant.

Although natives of the Orient, and extensively used there as food, taros and dasheens are much grown in tropical America. Both the corms and cormels or only one, depending on the variety, are suited for cooking. The petioles, leaves, and even the flowers if produced, after boiling in a solution of sodium bicarbonate to destroy the acridity, may be used as greens.

In Hawaii the national dish *poi* is prepared from the corm of a taro, and in the West Indies and Gulf States of the United States dasheens are common substitutes for potatoes. Aside from the taros which have been for some time sold in the Chinese Quarters, dasheens are now being introduced into the markets of the northern cities, where they should prove to be popular and economical substitutes for potatoes. Flour prepared from dried taros is much used in the West Indies.

MACROSCOPIC STRUCTURE.—The primary fleshy subterranean organ of the taros and dasheens is a *corm*. From the sides of the corms of the dasheens, secondary corms or *cormels* (Fig. 32) develop, one or more of which may acquire the characters of the primary corm.

The shape of the corm or cormel varies from elongated to nearly spherical. Rings or leaf scars, also eyes or buds, mark the surface. A brown, shaggy, bark-like covering is present between the rings; the skin beneath this covering is white, green, red, or purple, and the flesh, although commonly whitish, may be yellow, orange, red, or purple. A cross section shows the numerous bundles as spots in the starchy ground tissue. A yellowish latex exudes from the cut surface. As noted by Barrett[1] the latex thickens, turns brown, and forms a viscous gum.

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[1] **U. S. Dept. Agr. 1924, Bul. 1247.**

MICROSCOPIC STRUCTURE (Fig. 33). **Cork** (*su*).—The cells are in a considerable number of tiers—twenty to thirty in a corm 5 cm. in diameter, more in larger corms. In surface view the cells are polygonal. Those on the scales are longitudinally elongated over the bundles.

Cortex.—There is no sharp demarcation between the parenchyma of the cortex and the central cylinder. Both contain *starch grains* in the ground tissue and often *raphides* in special sacs. Here and there are present branching and anastomosing *latex tubes,* the contents of which take on a brown color due to the presence of tannins. According to De Bary, resinous matter is also a constituent.

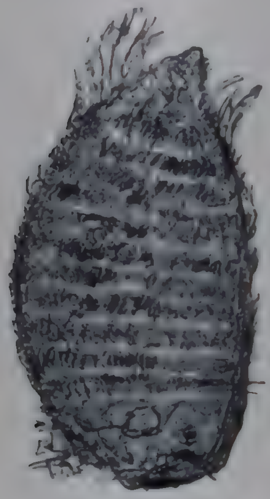

FIG. 32.

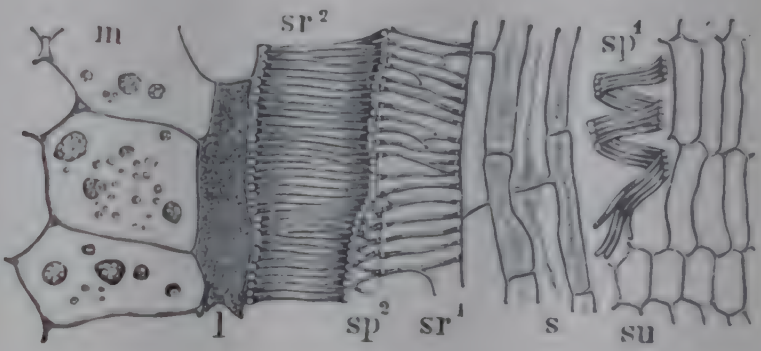

FIG. 33.

FIG. 32.—Taro (Dasheen). Cormel of Chinese variety. × ½. (A.L.W.)

FIG. 33.—Taro (Dasheen). Elements of cormel in longitudinal section. *su* fragment of cork layer; *s* sieve tube; sp^1 and sp^2 spiral vessels; sr^1 and sr^2 spiral-reticulated vessels; *l* latex or resin tube; *m* ground parenchyma with starch grains. × 160. (A.L.W.)

Central Cylinder.—The *ground parenchyma* (*m*) is made up of cells somewhat larger but thinner-walled than those of the cortex. The *starch grains* vary in size in different samples and sometimes in different corms of the same sample, as the following measurements, by the writers, of the largest grains illustrate: Trinidad dasheen 5 cm. in diameter from R. A. Young, 11 μ; sample similar to the last, from New York Chinatown, 9 μ; sample consisting of two corms and three cormels of dasheen from R. A. Young, 11 μ, in all but one corm in which it was only 4 μ; two samples of taro from R. A. Young, 7 μ and 3 μ; sample of taro starch of unknown origin, 9 μ. Barrett[1] gives 3 μ as the maximum. In shape, the grains are polygonal or truncated according to their position in small aggregates from which they readily separate. See Commercial Starches, Volume I.

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[1] U. S. Dept. Agr., Bur. Plant Ind. 1910, Bul. 164.

Raphides may or may not be present. For example, in Trinidad dasheen, according to Young, they are absent or few; in Penang taro they are said to be present, although in a sample examined by the writers none was found. They are especially numerous in the leaves and petioles. Black's experiments[2] indicate that the acridity of aroids is due to the presence of raphides.

Fibro-vascular Bundles.—The *vessels* are mostly large (up to 80 μ), either spiral (sp^1) or spiral-reticulated (sr^1, sr^2). The spirals may be loosely or closely wound and may consist of several strands. Cross sections show that the vessels form curved rows on both sides of the phloem, often nearly completely enclosing it. The *sieve tubes* (*s*) have indistinct callus plates. *Bast fibers* are absent in the bundles of the fleshy tissue but occur in the scales.

Latex tubes (*l*) accompany the bundles, sending off branches into the ground tissue. They also occur in the phloem and away from the bundles in the ground parenchyma.

Chief Structural Characters.—Corms and cormels rounded, with transverse rings and brown shaggy covering over intervening surface; inner skin and flesh white or variously colored; cut surface dotted with vessels and drops of latex.

Cortex in many rows. Parenchyma of cortex and central cylinder with starch grains up to 11 μ from or in aggregates. Vessels spiral or spiral-reticulated, up to 80 μ, the spiral vessels often with several strands. Latex tubes adjacent to bundles or detached in ground parenchyma.

CHEMICAL COMPOSITION.—The analyses of taro and dasheens in the following table are by Kellner,[3] Blasdale,[4] Agcaoili,[5] Hemmi,[6] and Chung and Ripperton.[7] Blasdale notes that his results on starch are much higher than those of Kellner. Included also in the table is a summary of 28 analyses by Quisumbing[8] of taros, dasheens, yautias, yeddos, and perhaps other aroids which, being distinguished by native names, cannot be separately classified.

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[1] U. S. Dept. Agr. Bur. Plant Ind. 1910, Bul. **164**.

[2] Am. J. Bot. 1918, **5**, 447.

[3] Landw. Vers.-Stat. 1884, **30**, 42.

[4] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[5] Philippine J. Sci. 1916, **11**, 91.

[6] J. Col. Agr. Hokkaido Imp. Univ. 1918, **8**· 33.

[7] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[8] Philippine Agr. For. 1914, **3**, 85, 99.

COMPOSITION OF TAROS AND DASHEENS

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Kellner	80.65	2.00	1.39	0.17	15.63	......	6.52	0.70	0.85
Blasdale:									
Small	74.20	1.70	1.67	0.27	21.54	1.15	17.95	0.98	1.31
Large	67.51	1.89	1.62	0.16	28.68	1.86	25.32	0.66	1.10
Agcaoili	63.21	1.29	....	0.39	33.51	......	......	1.59	1.01
Hemmi	79.49	2.44	1.81	0.16	16.24*	0.16†	14.67	0.76	0.93
C. and R.:									
Chinese ‡	72.37	1.48	....	0.11	24.23	......	......	0.61	1.20
Japanese	81.40	1.44	....	0.07	15.34	......	......	0.63	1.12
Quisumbing:									
Min. §	49.31	0.51	....	0.08‖	....	trace	4.99	0.14‖	0.42‖
Max. §	80.46	2.88	....	0.20‖	....	trace	25.04	1.14‖	2.25‖

* Reducing sugars 0.12, dextrin 0.14, galactan 0.60, and pentosans 0.66%.

† Non-reducing sugars. ‡ Peeled. § Includes yautias, yeddos, etc. ‖ 5 samples. Reducing sugars 0.26 to 0.50, dextrin 0.78 to 4.03% also given.

Chung and Ripperton also analyzed the shoots and petioles respectively, with results as follows: water 95.39 and 93.20, protein 0.92 and 0.79, fat 0.09 and 0.13, nitrogen-free extract 2.17 and 3.52, fiber 0.58 and 1.44, and ash 0.85 and 0.92 per cent.

Acids.—In a sample of dasheen Viehoever, Kunke, and Mastin[1] found *oxalic acid* 0.49 per cent.

Carbohydrates.—Hemmi[2] found that the hemicellulose of the corm and a mucilage that was separated both yielded on hydrolysis *d*-galactose and *l*-arabinose.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[3] found 1.34 per cent, dry basis.

Mineral Constituents.—Chung and Ripperton[4] found:

	Calcium	Iron	Phosphorus	Alkalinity *
	%	%	%	%
Corm:				
Chinese (peeled)	0.023	0.0017	0.069	14.5
Japanese	0.013	0.0015	0.032	15.4
Shoots	0.013	0.0017	0.030	10.5
Petioles	0.066	0.0101	0.032	13.6

* Expressed as cc. normal acid per 100 grams fresh vegetable.

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[1] Science 1917, **46**, 546.

[2] Loc. cit.

[3] Philippine Agr. 1932, **21**, 53.

[4] Loc. cit.

YAUTIA

Xanthosoma spp.

Under the general name of yautias are included species and varieties of *Xanthosoma*. According to Young[1] the yautias, which include Rolliza, nut eddo, pica-uncucha, malanga coloré, and belembe, are distinguished from the taros in having the sinus of the leaf open to the leaf stalk. Corms and cormels of some varieties are inedible because of their acridity; certain varieties, however, with acrid corms have edible cormels. Yautia flour is said to be of excellent quality. The belembe (*X. brasilense* (Desf.) Engl.) is grown solely for greens which are stated to be of particular excellence.

MACROSCOPIC STRUCTURE.—Practically the same as of the taro. In the samples examined numerous bundles run transversely in a zone 3 to 5 mm. from the surface which might be mistaken for a cambium zone such as is found in exogenous roots and tubers.

MICROSCOPIC STRUCTURE.—In general histological structure, the yautias and taros are practically the same; the *starch grains*, however, are larger in the yautias, reaching a maximum in samples examined by the authors of 17 μ. Barrett[2] reports a maximum of 20 μ. As is true also of the taros, the largest starch grains occur at the base of the corm or cormel, the smallest at the top.

CHEMICAL COMPOSITION.—Analyses of white and yellow yautias made at the Maine Experiment Station, as reported by Barrett,[3] follow:

COMPOSITIONS OF YAUTIAS (BARRETT)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
White yautia.....	70.0	1.7	0.2	26.3	0.6	1.2
Yellow yautia.....	70.0	2.5	0.2	26.1	0.6	0.6

Analyses by Quisumbing of yautias grown in the Philippines are included with taros and dasheens in the table given under Taro on the preceding page.

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[1] U. S. Dept. Agr. 1924, Dept. Bul. **1247**.

[2] U. S. Dept. Agr., Bur. Plant Ind. 1910, Bul. **164**.

[3] Porto Rico Agr. Exp. Sta. 1905, Bul. **6**.

ARUM

Arum maculatum L. and *A. italicum* Lam.

Cuckoopint (*A. maculatum*) and *gigaro* (*A. italicum*) grow wild in wet woods of southern Europe, and their corms and cormels, although peppery when fresh, are edible after drying or boiling. Their chief use appears to be for starch manufacture (see Arum Starch, Volume I) or cattle food. Both species have been successfully cultivated.

MACROSCOPIC STRUCTURE.—The cormels of *A. maculatum* are small (1 cm.), those of *A. italicum* larger.

MICROSCOPIC STRUCTURE.—The structure is much the same as that of taro and other aroids, small, polygonal *starch grains* (up to 22 μ), *bundles*, and *raphides* being the conspicuous elements.

CHEMICAL COMPOSITION.—Analyses of cormels of *A. italicum* by Pantanelli[1] follow:

	Water	Protein	Protein, pure	Sugars, reducing	Dextrin	Starch	Ash
	%	%	%	%	%	%	%
Two years old....	65.31	1.75	0.81	0.15	0.46	20.70	0.53
Three years old..	64.67	1.50	0.50	0.03	0.36	21.74	0.58

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[1] Staz. sper. agr. ital. 1918, **51**, 69.

TUBERS OF THE YAM FAMILY

(*Dioscoreaceæ*)

A NUMBER of species of *Dioscorea* yielding edible tubers are known as yams.

Starch grains, *raphides* of the cork and cortex, and *stone cells* of the pericycle are the noteworthy microscopic characteristics.

The solids consist chiefly of *starch.*

YAM

Dioscorea spp.

Fr. Igname. Sp. Ñame. It. Ignamo. Ger. Yamwurzel. Chin. Tai-sue. Jap. Naga-imo.

According to R. A. Young,[1] *D. alata.* L. is the most important and most widely distributed of the six species of yam commonly grown for their edible tubers in the West Indies, whence they have been introduced by the Department of Agriculture into the United States, the other species being the yellow Guinea, affou, or Congo yam (*D. cayenensis* Lam.), the lesser yam (*D. esculenta* (Lour.) Burkill), the acom (*D. latifolia* Benth.), the white Guinea or negro yam (*D. rotundifolia* Poir.), and the yampi or cush-cush (*D. trifida* L.f.).

The Chinese yam (*D. Batatas* Decne.) produces tubers of good quality but so deep seated in the soil as to render harvesting exceedingly difficult. This species, under the name of cinnamon vine, is grown as an ornamental in the temperate zone.

According to Oshima and Tadokoro,[2] both *D. Batatas* and *D. japonica* Thunb. are common articles of food in Japan.

Excellent photographs of the tubers of different species appear in Young's bulletin.

MACROSCOPIC STRUCTURE.—As in the case of the sweet potato, there appears to be a difference of opinion as to whether the tuberous organ is a true tuber or a tuberous root. Commonly it is referred to as a tuber, but certain characters are more in keeping with a tuberous root. De Bary, as noted below, refers to them as "tuberously developed roots."

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[1] U. S. Dept. Agr. 1923, Bul. **1167**.

[2] J. Col. Agr. Tohoku Imp. Univ. Sapporo, Japan, 1911, **4**, 243.

As stated by Young, the *tuberous roots* of most of the varieties of the greater yam have white flesh and white or yellowish inner skin, but some have yellow flesh, others white flesh and reddish or purple inner skin, and still others, purple flesh. In some varieties the roots weigh as much as 45 kilos. Those of large size are often irregular in shape, while those of moderate size are commonly spindle- or club-shaped, or somewhat branched at the end.

On the surface are numerous rootlets often arising from pronounced warts. A cross section shows rounded patches of a light color varying from less than 1 mm. in the rind to over 2 mm. in the center where they are farther apart. Each of these consists of starchy tissue with a fibro-vascular bundle in the center. The ground tissue separating these spots is of a darker color and starch-free. A brown peripheral line is the cork tissue, and a similar line about 1 mm. from the last is the stone-cell layer.

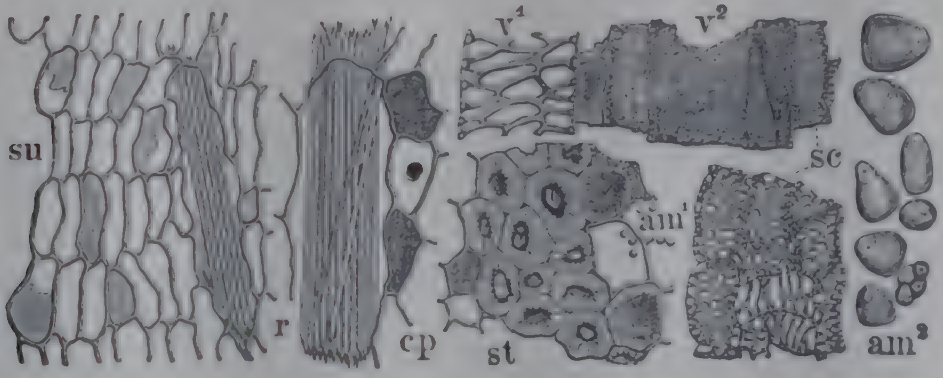

Fig. 34.—Yam. Elements of tuber in longitudinal section. *su* cork and *cp* cortex parenchyma, each with a raphides group (*r*); *st* stone cells (with crystals) of pericycle; v^1 and v^2 vessels of fibro-vascular bundle; *sc* reticulated sclerenchyma cells of bundle sheath; am^1 starch grains of cells adjoining pericycle; am^2 starch grains of ground tissue. × 160. (A.L.W.)

MICROSCOPIC STRUCTURE (Fig. 34).—The following is based on a study of the Barbadoes Red Yam.

Cork (*su*) forms fifteen or more tiers of cells. In surface view the cells are transversely elongated but are not arranged in regular rows. On the warts the cells are smaller and more nearly isodiametric. *Raphides* (*r*) occur in special sacs several times longer than the normal cork cells. Varieties appear to differ as to the amount or even the presence of raphides which in the yam, as in the dasheen, are the cause of the acridity.

Cortex.—Adjoining the cork, the cells of the *cortex parenchyma* (*cp*) are large; adjoining the pericycle they are smaller. Here as in the cork there are *raphides* in special sacs. If the skin is colored, the cells of both cork and cortex contain the color in solution.

Pericycle.—*Stone cells* (*st*), several deep, form a zone separating the cortex from the central cylinder. Most of the stone cells have thick walls and contain a monoclinic prism, but some in the inner part have thin walls and do not contain crystals. The cell lumen is often excentric.

Central Cylinder.—The *ground parenchyma*, forming a kind of sheath about the bundles, contains starch grains; these complexes are separated from each other by starch-free parenchyma forming the glassy meshes seen with the naked eye. Adjoining the pericycle, the *starch grains* are small—often minute (*am*¹)—farther inward they reach 65 μ (*am*²). The hilum is excentric (1 : 3 to 1 : 6), located in the small end of the grain which is often bent; both hilum and rings are indistinct. Common forms are pear-shaped, elliptical, and triangular. See Commercial Starches, Volume I.

Fibro-vascular Bundles.—De Bary[1] in considering collateral bundles states: "Among parts belonging to the category of roots they occur only in the tuberously developed roots of *Dioscoreæ* (*D. Batatas*)." Large *reticulated vessels* (v^1), with bold network, still larger, angular *pitted vessels* (v^2), and smaller forms of both types make up the vascular system. The *sclerenchyma cells* (*sc*) of the bundle sheath are variously pitted or reticulated.

CHIEF STRUCTURAL CHARACTERS.—Root-tubers commonly spindle- or club-shaped. Inner skin white, yellow, reddish, or purple; flesh white, yellow, or purple with numerous fibro-vascular bundles.

Cork cells in fifteen or more tiers, transversely elongated. Cork and cortex containing raphides sacs. Pericycle of stone cells mostly thick-walled each containing an oxalate prism. Ground tissue surrounding bundles with elongated starch grains up to 65 μ, the excentric hilum being in the narrow, often bent, end. Vessels of various sizes, often pitted or reticulated. Cells of bundle sheath reticulated.

CHEMICAL COMPOSITION.—The fact that certain varieties of sweet potatoes are known as yams has led to much confusion, the more unfortunate because of the wide separation of the two plants in the scheme of classification. The true yams (*Dioscorea*) are monocotyledonous plants whereas the sweet potato (*Ipomœa*) is a dicotyledonous plant. Of the 45 analyses which König gives in his Compilation under the head of Bataten (*Dioscorea Batatas* Decne. = *D. japonica* Thunb.), about two-thirds are obviously of sweet potatoes.

The analyses of yams given in the following table include those by

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[1] Comp. Anat. Phan. Ferns, Oxford, 1884, p. 319.

Eberhardt and Bloch[1] of I *D. aculata* (cu-cai-mo), II *D. purpurea* (cu-cot-gian), III *D. alata* var. *purpurea* (cu-cam), IV *D. purpurea* (cu-cot-gian), V *D. cirrhosa* (cu-o-rong), VI *D. oppositifolia* (cu-mai), and VIa same as preceding but small tubers, all grown in Annam and Tonkin; by Agcaoili[2] of *D. esculenta* grown in the Philippines; and by Hemmi,[3] Adolph,[4] Sherman and Wang,[5] and Chung and Ripperton[6] of *D. Batatas* grown in Japan, China, China, and Hawaii respectively:

COMPOSITION OF YAMS

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sugars, non-reducing	Starch	Fiber	Ash	Alc. ext.*
	%	%	%	%	%	%	%	%	%	%
E. and B.:										
I	69.89	1.87	0.04	......	0.26	0.39	24.52	1.51	0.63	1.08
II	67.38	1.31	0.06	......	0.09	0.23	27.35	1.23	1.15	0.68
III	65.40	2.37	0.03	......	0.21	0.51	28.76	1.35	0.68	0.64
IV	66.85	1.12	0.04	......	0.46	0.47	27.93	1.40	0.67	0.61
V	65.52	1.37	0.04	......	0.18	0.22	29.26	0.83	0.89	0.04
VI	62.55	1.12	0.04	......	0.08	0.25	33.14	0.70	1.08	0.56
VIa	66.89	1.50	0.04	......	0.10	0.35	27.58	0.73	1.51	1.15
Agcaoili:										
Tugui	67.49	1.50	0.19	18.80	......	......	......	0.95	1.07	
Ubi	63.70	2.86	0.05	27.31	......	......	......	1.03	1.45	
Hemmi	70.50	3.00	0.11	24.76†	0.70	1.51	28.13	0.65	0.98	
Adolph	76.80	2.21	0.06	19.63	......	......	......	0.61	0.69	
S. and W.	79.84	1.73	0.08	17.24	......	......	......	0.33	0.78	
C. and R.	78.23	1.11	0.12	18.60	......	......	......	0.96	0.98	

* Sugars deducted. † Pentosans 0.66%, dextrin 0.49%.

The variation in composition between the samples of the different species is scarcely more than would be expected between different samples of the same species. The analyses bring out only one distinction from sweet potatoes, namely, the lower fat content, and that is quite possibly due to method of analysis.

Mucin.—Ishii[7] separated from the yam a slimy substance which he concluded belongs to the mucins.

[1] Bul. sci. pharmacol. 1909, **16**, 509.
[2] Philippine J. Sci. 1916, **11**, 91.
[3] J. Col. Agr. Hokkaido Imp. Univ. 1918, **8**, 33.
[4] Philippine J. Sci. 1926, **30**, 287.
[5] Ibid. 1929, **38**, 69.
[6] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.
[7] Bul. Col. Agr. Tokyo Imp. Univ. 1894–7, **2**, 97.

Oshima and Tadokoro[1] demonstrated the presence of the glucosamin group in the yam mucin and of glutamic acid, tyrosin, and leucine in the protein residue from the glucosamin.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[2] found in the yam 1.56 per cent, dry basis.

Enzymes.—Tadokoro[3] discovered a mucin-coagulating enzyme in the tubers of *D. Batatas* which is different from chymase, the milk-coagulating enzyme.

Mineral Constituents.—Chung and Ripperton[4] report the following figures in percentages of the root: calcium 0.008, phosphorus 0.041, and iron 0.0074 per cent.

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[1] Loc. cit.

[2] Philippine Agr. 1932, **21**, 53.

[3] Trans. Sapporo Nat. Hist. Soc. 1915, **5**, 193.

[4] Loc. cit.

RHIZOMES OF THE WATER-LILY FAMILY

(*Nymphæaceæ*)

Rhizomes of the lotus, the representative of this family, have enormous *air passages* and *spiral vessels*, also *bast fibers*. The *starch grains* are characteristic.

Chemical analysis shows that the solids consist largely of *starch* together with smaller amounts of *sugars*.

LOTUS

Nelumbo nucifera Gaertn. = *Nelumbium speciosum* Willd.

Fr. Lotus. It. Loto. Ger. Lotos. Chin. Lin-ngou. Jap. Hasu-no-ne.

Although known as the sacred or Egyptian lotus, the plant is a native of India, Persia, Cochin China, the Philippines, and Australia. The lotus of Egypt is *Nymphæa Lotus* L.

Both fresh rhizomes and dried slices are sold in the Chinese Quarters of American cities. The fresh rhizome is eaten boiled and raw and from it is prepared starch.

MACROSCOPIC STRUCTURE.—The *rhizome* (Fig. 35) is 5 to 7 cm. thick, obscurely six-angled, with constrictions at the nodes, the whole appearing like links of sausage. Slices of the rhizome, such as are dried and placed on the market (Fig. 36, I), show seven large and several small air passages arranged about an air passage in the center.

MICROSCOPIC STRUCTURE.—The arrangement of the bundles and air passages has been studied by Wigand[1] and Trécul[2] and described and pictured by De Bary[3] on their authority. Instead of a single ring of bundles with a cambium zone, as is the rule in most dicotyledonous stems and their modifications, the bundles are distributed through a parenchymatous ground tissue much as in the stem of monocotyledons such as maize.

Epiderm.—The cells are small, polygonal, and characterless.

Cortex.—Isodiametric *parenchyma cells* with starch grains form a tissue, several cells thick, passing into the ground tissue in which the bundles are distributed.

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[1] Bot. Ztg. 1871, p. 816.

[2] Ann. sci. nat. Ser. I, 5, 162.

[3] Comp. Anat. Phan. Ferns, Oxford, 1884, p. 255.

Central Cylinder.—Both the cells and the starch grains in the *ground tissue* are larger than those of the cortex. The *starch grains* (see Lotus Rhizome Starch, Volume I) are commonly elongated, up to 65μ. One end of each grain is rounded and contains the excentric hilum; the other end is usually truncated and in addition may be narrowed or broadened.

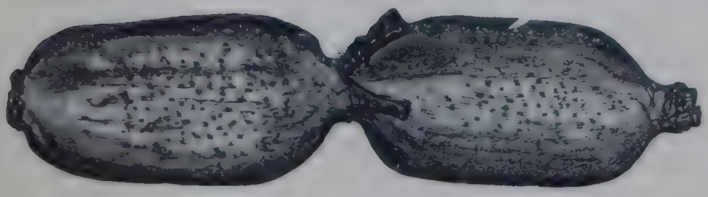

Fig. 35.

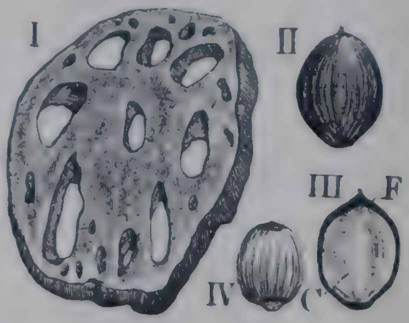

Fig. 36.

Fig. 35.—Lotus rhizome. × ¼. (A.L.W.)

Fig. 36.—Lotus. I slice of rhizome, dried. II fruit, entire. III fruit, longitudinal section, showing *F* pericarp and *C* cotyledon. IV seed with longitudinally striate spermoderm. × ½. (A.L.W.)

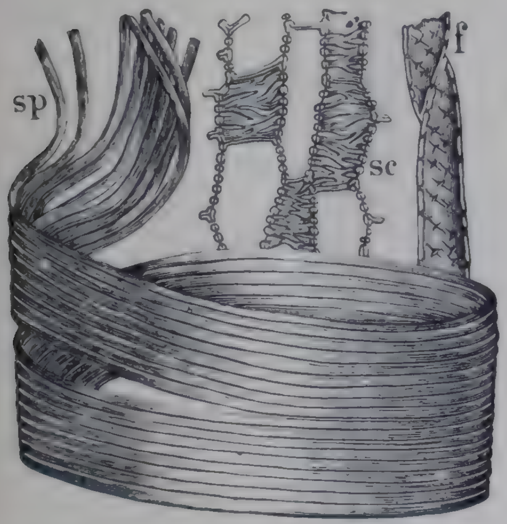

Fig. 37.—Lotus. Elements of fibro-vascular bundle of rhizome in longitudinal section. *sp* spiral vessel 265µ broad; *f* bast fiber; *sc* sclerenchyma cells adjoining spiral vessel. × 160. (A.L.W.)

Fibro-vascular Bundles (Fig. 37).—The arrangement of the 252 bundles, as shown by De Bary, is in ten concentric rings, the phloem of those in the third and fifth ring from the center being turned toward the center, while that of the others is turned toward the periphery. Vessels of the fourth, fifth, and sixth rings form single radial rows in the ground tissue separating the air passages, while those in the other rings follow a more complicated system.

The *bast fibers* (*f*) are broad but thin-walled; the *sclerenchyma cells* (*sc*) accompanying the vessels are polygonal in form and have reticulated walls. The *vessels* (*sp*) are of spiral form with as many as ten or more strands. Their enormous breadth is noted by Caspary,[1] who records 567 μ as the maximum. Fig. 37 shows a vessel, from a rhizome sold in New York Chinatown, of oval form measuring 352 μ through the larger and 192 μ through the shorter diameter. A comparison of the vessel in this cut with others in this work magnified the same number of diameters shows the great range in size of spiral vessels.

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[1] Monatsb. Berlin Akad. 1862, **7**.

CHIEF STRUCTURAL CHARACTERS.—Rhizomes sausage-like, showing, in section, air passages.

Epidermal cells in longitudinal rows. Ground tissue containing elongated starch grains, up to 65 μ, with excentric hilum. Bundles in concentric circles with broad but thin-walled bast fibers, pitted sclerenchyma cells, and spiral vessels up to more than 500 μ.

CHEMICAL COMPOSITION.—Single analyses of the rhizome by Blasdale,[1] Adolph,[2] and Chung and Ripperton[3] follow:

COMPOSITION OF LOTUS RHIZOMES

	Water	Protein	Protein, pure	Fat	N.-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Blasdale......	84.26	1.57	0.91	0.19	12.46	2.18	0.33	7.71	0.76	0.76
Adolph ("Ou")	86.72	1.66	......	0.09	9.67	......	.....	......	0.76	1.10
C. and R.....	83.20	2.35	......	0.08	12.35	......	.....	......	0.69	1.33

Mineral Constituents.—Chung and Ripperton found: calcium 0.025, iron 0.0027, and phosphorus 0.086 per cent; also alkalinity of ash 9, expressed as cubic centimeters of normal acid per 100 grams of fresh vegetable.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Philippine J. Sci. 1926, **30**, 287.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

TUBERS OF THE MINT FAMILY

(*Labiatæ*)

This large, widely distributed family is of great economic importance, and many genera are cultivated because of the volatile-oil content of the stems and leaves used as drugs and condiments. One species, the Japanese potato, produces an edible tuber much prized in the Orient and introduced into Europe and America some years since.

Characteristic chemical constituents are *stachydrine*, a nitrogenous base, and *stachyose*, a tetrasaccharide.

JAPANESE POTATO

Stachys sieboldii Miq.

Fr. Crosne du Japan. Ger. Japan Knollen. Chin. Kan-lu.
Jap. Daima-gik.

This remarkable vegetable is a staple crop in Japan and has been grown successfully in Central Europe.[1] Hanausek[2] has shown that this species is not *S. tuberifera* Naud.

MACROSCOPIC STRUCTURE.—The slender jointed *tubers* grow at the ends of the underground stem, reaching a length of 5 cm. Two opposite scales (leaves) are present in each constriction.

MICROSCOPIC STRUCTURE.—The minute structure is exceedingly simple, the *epiderm* of polygonal cells and stomata, the remarkably small cells of the *parenchyma*, and the *bundles* with small sieve tubes being the only noteworthy tissues. *Stachyose* is in solution. *Starch* is said to be present in freshly dug roots.

CHEMICAL COMPOSITION.—An analysis by Strohmer and Stift[3] made in Austria and one by Sherman and Wang[4] made in China appear on the next page.

Proteins.—The total nitrogen was found by Strohmer and Stift[3] to consist of pure protein nitrogen 19.01, nuclein nitrogen 8.13, ammonia

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[1] Just: Deut. Landw. Presse 1891, 282.

[2] Forsch. Ber. Lebens., 1894, **1**, 72.

[3] Oester. ungar. Z. Zuck. Ind. Landw. 1891, **20**, 803.

[4] Philippine J. Sci. 1929, **38**, 69.

COMPOSITION OF JAPANESE POTATOES

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Strohmer and Stift	78.05	4.31	1.17	0.16	15.55*	0.73	1.20
Sherman and Wang	77.13	2.88	....	0.08	17.99	0.82	1.10

* Stachyose 13.92%.

nitrogen 7.84, amido acid amide nitrogen 42.96, amido acid nitrogen 16.26, and undetermined nitrogen 5.80 per cent; total 100 per cent.

Nitrogenous Bases. *Stachydrine* ($C_7H_{13}O_2N \cdot H_2O$).—Engeland[1] states that stachydrine is a completely methylated amino acid, the basis being α-pyrrolidine-carboxylic acid, and is identical with *n*-methylhygrinic acid described by Willstätter.[2] Schulze and Trier[3] isolated stachydrine from the tuber, confirmed Willstätter's synthesis, and assigned to it a tentative structural formula. Ackermann, Holtz, and Reinwein[4] suggest its possible identity with actinine of sea-anemones.

Other bases shown by Schulze and Trier[5] to be present are *choline*, *trigonelline*, and *arginine*.

Carbohydrates.—*Stachyose* ($C_{24}H_{42}O_{21}+4H_2O$), first isolated from the Japanese potato by Planta[6] and later found by Planta and Schulze[7] to constitute 14 to 73 per cent of the solids of the tuber, was shown by Tanret[8] to be identical with mannotetrose, a tetra-saccharide present in the manna of the ash tree. It is probably identical with the lupeose found by Schulze[9] in lupines. It has the formula:

$$\underset{\text{Levulose}}{C_6H_{11}O_5} - O - \underset{\text{Dextrose}}{C_6H_{10}O_4} - O - \underset{\text{Galactose}}{C_6H_{10}O_4} - \underset{\text{Galactose}}{C_6H_{11}O_5}$$

Mannotriose is closely related, the levulose radical being eliminated.

Stachyose is a colorless crystalline substance with a sweet taste, readily soluble in water, strongly dextrorotatory (anhydride $[\alpha]_D+$ 148°), hydrolyzable to mannotriose and levulose by invertase and by acetic acid and to its component hexoses by strong acids. Vintilesco[1] states that emulsin, acting after invertase, causes complete hydrolysis to one molecule of glucose and two molecules of galactose. It is nonreducing, does not decompose with dilute alkalies, and as shown by Barther and Bierry[2] and by Bierry[3] is not digested by vertebrates but is acted on by enzymes present in certain mollusks and crustaceans.

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[1] Arch. Pharm. 1909, **247**, 463.

[2] Ber. 1900, **33**, 1160.

[3] Ibid. 1910, **42**, 4654.

[4] Z. Biol. 1924, **81**, 61.

[5] Z. physiol. Chem. 1910, **67**, 59.

[6] Landw. Vers.-Stat. 1880, **25**, 473.

[7] Ber. 1890, **23**, 1692; 1891, **24**, 2705.

[8] Compt. rend. 1904, **136**, 1569.

[9] Ber. 1910, **43**, 2230.

Pectin.—Charpentier,[4] by precipitation of the aqueous extract with two volumes of 86 per cent alcohol containing 1 per cent of hydrochloric acid, obtained 0.26 per cent of pectin with a rotation +119.8° and found that it was coagulated by pectase.

Mineral Constituents.—Bailey[5] reports, in a sample containing water 78.9, protein 12.04, and ash 1.09 per cent, the following constituents of the ash: K_2O 0.64, CaO 0.03, and P_2O_5 0.19 per cent.

Minor Mineral Constituents. *Aluminum.*—Tuber 73.7 mg. per kilo, dry basis (Bertrand and Lévy).[6]

Zinc.—Tuber 3.2 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

[1] J. pharm. chim. 1909, **30**, 167.

[2] Compt. rend. soc. biol. 1908, **65**, 735.

[3] Compt. rend. 1911, **152**, 904; Biochem. Z. 1912, **44**, 446.

[4] Bul. soc. chim. biol. 1924, **6**, 142.

[5] Cornell Agr. Exp. Sta. 1891, Bul. **37**, 382.

[6] Compt. rend. 1931, **192**, 525.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

TUBERS OF THE NIGHTSHADE FAMILY

(*Solanaceæ*)

THE potato, described below, is the only important species of the family yielding edible tubers.

The *starch grains, crystalloids*, and the *bicollateral bundles* with *meshes of vessels* are the histological elements of chief interest.

Potatoes are preeminently a starchy food, although the protein adds to the nutritive properties. The starch may exceed three-quarters of the dry matter.

POTATO

Solanum tuberosum L.

Fr. Pomme de terre. Sp. Patata. It. Patata. Ger. Kartoffel.

Since its introduction into Europe from the highlands of Chile and Peru toward the close of the sixteenth century, the potato has had a profound influence on the civilization of temperate regions.

The great number of varieties have been produced by breeding and cultivation, the chief points of difference being size, form, depth of eyes, color, starch content, productiveness, and resistance to disease. There are brown-, yellow-, orange-, pink-, purple-, and black-tubered varieties, the color being largely in the skin and outer cortex. The wild species and certain of the earlier varieties produce an abundance of seed in a fruit or seed ball about 1 cm. in diameter, but most of the improved varieties ripen seed sparingly if at all.

In the United States, potatoes are used largely as human food, only the culls being utilized for cattle food or technical purposes, whereas in Europe, particularly in Germany, large quantities serve as cattle food and for the manufacture of starch, glucose, dextrin, and spirits. They are placed on the market almost exclusively as the whole tuber, dried potatoes and true potato flour—potato starch is often incorrectly termed potato flour—being of small importance and canned potatoes practically unknown except as an ingredient of canned hash and soups.

Thin slices fried in deep fat and salted, known in the United States as Saratoga chips or potato chips, are not only prepared in the kitchen as needed but also on a commercial scale and sold in waxed containers.

MACROSCOPIC STRUCTURE.—While the morphological nature of the sweet potato is perhaps still unsettled, there is no doubt that the common potato is a swelling at the end of an underground stem, hence a true tuber. At any early stage of development (Fig. 38, left) distinct scales (abortive leaves) subtending the eyes (shoot buds) are clearly seen but later disappear leaving a marked transverse wrinkle. The surface of a normal mature *tuber*, exclusive of the eyes, is quite smooth with small, round lenticels, although lamellæ of the outer cork often slough off here and there; the surface of scabby potatoes, however, is much roughened.

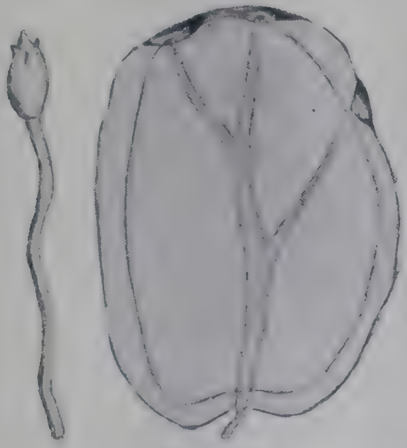

FIG. 38.

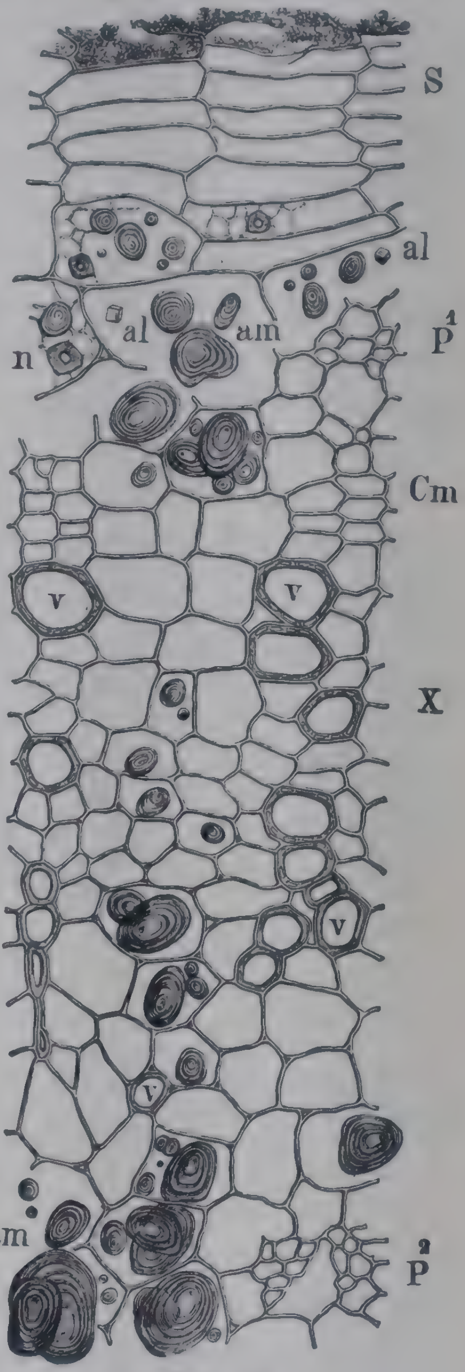

FIG. 39.

FIG. 38.—Potato. Left, tuber in early stage with scales subtending eyes. × 1. Right, mature tuber in longitudinal section showing cortex separated from the pith by the bundle zone, also pith core with branches to the eyes. × ½. (A.L.W.)

FIG. 39.—Potato. Tuber in cross section. *S* cork; *al* crystalloids and *n* cell nuclei contained in outer cortex; *am* starch grains; P^1 outer phloem; P^2 inner phloem; *X* xylem with *v* vessels; *Cm* cambium. × 160. (A.L.W.)

A median longitudinal section (Fig. 38, right) shows the cortex separated from the pith by the bundle zone and the core of the pith with branches running to the eyes. The thickness of the cortex reaches about 1 cm. in large potatoes (about 8 cm. broad). Both the bundle zone (1 to 2 mm. thick), which meets the eyes in their depressions, and the core of the pith with its branches are recognized by their glassy appearance. The greater part of the whole tuber is pith, and the proportion is still greater after paring with a knife which, unlike scraping, removes a considerable portion of the cortex.

Sometimes irregular cavities with dark-colored, tough lining form in potatoes, the nature of which is noted below. The sprouts, which grow out from the eyes in the Spring, are white and have numerous hairs.

MICROSCOPIC STRUCTURE.—The various tissues of the plant, especially those in the tubers such as cork, bundles, aleurone grains, and starch grains, have been subjects for journal articles and descriptions in the treatises, but comprehensive descriptions of so important a vegetable have been singularly few. Of recent articles, those by Reed[1] and Artschwager[2] are particularly instructive.

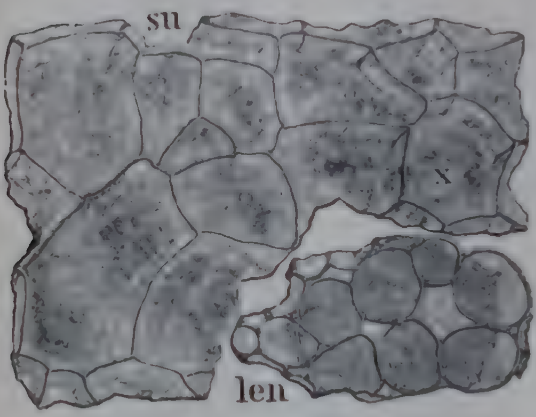

Fig. 40.

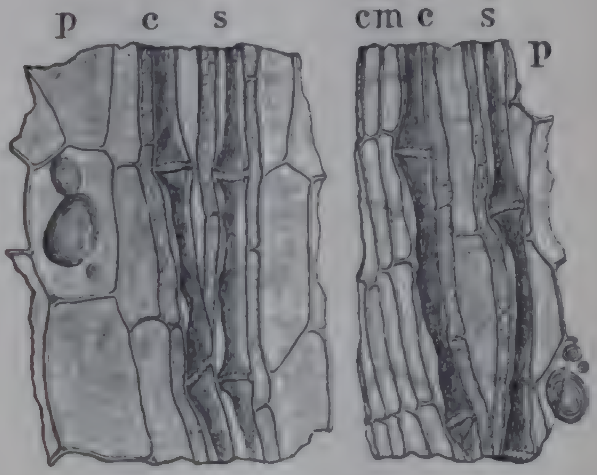

Fig. 41.

Fig. 40.—Potato. Cork of tuber in surface view. *su* cells of the smooth cork with *x* central cell of a radiating group. *len* cells of a lenticel. × 160. (A.L.W.)
Fig. 41.—Potato. Outer (right) and inner (left) phloem of bicollateral fibrovascular bundle of tuber in longitudinal section. *cm.* cambium; *s* sieve tubes; *c* companion cells; *p* parenchyma. × 160. (A.L.W.)

Cork (Fig. 39, *S*; Fig. 40, *su*).—Strippings from a boiled potato, after ruptured cells have been scraped off, show that the cells are polygonal, isodiametric, or variously elongated, often with obvious division into daughter cells. Arrangement in transverse rows, so common in root vegetables, is not evident, but a score or more of cells are often arranged irregularly about a center, the intersection of such groups forming a bewildering pattern suggesting that frequently seen in tile pavements. In cross sections the outer cells with ruptured walls and adhering soil, also the several tiers of perfect cells, are clearly seen. Cells of the *lenticels* (Fig. 40, *len*) are small, rounded, often separated by intercellular spaces.

[1] Ann. Bot. 1910, **24**, 537.

[2] J. Agr. Res. 1918, **14**, 221; 1924, **27**, 809.

Cortex (Fig. 39).—Adjoining the innermost tier of cells of the cork (phellogen) is the outer cortex which is recognized by the isodiametric cells. These contain numerous *starch grains* (*am*) and occasional *crystalloids* (*al*). Proceeding inward, the cells and the large starch grains increase in size.

The *crystalloids* noted by Cohn[1] in 1859 and pictured by Unger[2] are characterized by their cubical form. With iodine in potassium iodine they stain bright yellow.

Stone cells occasionally occur in the cortex. A typical one measures 100 μ in diameter with finely pitted double walls 8 μ thick. Artschwager classifies the different varieties of potatoes according as stone cells are wanting, sparingly developed, or numerous. He also notes the presence of *tannin vesicles* near the bud, especially during sprouting.

Phloem (Fig. 39, P^1, P^2; Fig. 41).—Of special interest are the fibrovascular bundles of the potato tuber, as well as other parts of the plant, which are bicollateral with phloem on the inside as well as the outside of the xylem. The elements are *sieve tubes* (*s*), *companion cells* (*c*), and *ground parenchyma* (*p*). The cells of the ground parenchyma of both phloem and xylem groups are smaller than in the medullary tissues between and differ further in not containing starch grains. The xylem group, as shown in Fig. 39, is separated from the inner phloem group by several large cells with starch.

Phloem groups also are scattered through the tissues inside the bundle zone, that is, in the pith and the pith core with its branches; xylem tissues are restricted to the bundle zone.

Cambium (Fig. 39, *Cm*; Fig. 41, *cm*).—Typical cambium cells occur only in the bundle rays between the outer phloem and the xylem. Between neighboring bundle rays the cambium cells are replaced by normal large parenchyma cells.

Xylem (Fig. 39, *X*; Fig. 42).—A piece of potato pared down to the bundle ring, boiled, and carefully freed from the pith shows on being held up to the light the meshes formed by the vessels. On further boiling with 1 per cent sulphuric acid and mounting, the vessels are seen to have a great variety of markings and are connected by numerous side branches thus forming the network. Especially noticeable are double *spiral vessels* (*sp*) and broad *reticulated vessels* (r^3) with wide meshes. There are also present other types of *reticulated vessels* (r^1, r^2) and *pitted vessels* (*pi*), many with side branches.

Pith.—Aside from the occurrence of *phloem elements*, the tissue consists of large isodiametric *parenchyma cells* containing starch grains.

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[1] B. schles. Ges. vaterl. Cult. 1859, **37**, 72.

[2] Weiss: Anat. Pflanzen. Wien, 1878, p. 144.

Unlike that of roots, the parenchyma of the pith, as well as of the cortex and bundle zone, is not in marked radial rows as seen in either cross or longitudinal-radial section. The cells are somewhat rounded with small intercellular spaces at the angles, but sac-like cells readily separating as such, or cells with large intercellular spaces of the type found in the banana and sweet potato, are lacking.

A potato pared by cutting, not scraping, consists largely of pith. It is here that the *starch grains* reach their maximum size which for perfect normal grains is about 100 μ. When it reaches 110 μ, the grain is usually damaged or deformed, often with central rifts, enlarged hilum, or cracked edges, approaching the condition found in the cooked or sprouted tuber. Elliptical forms, with an excentricity of about 1 : 2, are the commonest among the large starch grains. When truncated or irregular at one end, the hilum is usually in the rounded or perfect end which is commonly the narrower. The greatest irregularity of form occurs in grains about the stem end; in other regions, they are commonly much more regular than drawn by most authors. See also Potato Starch, Volume I.

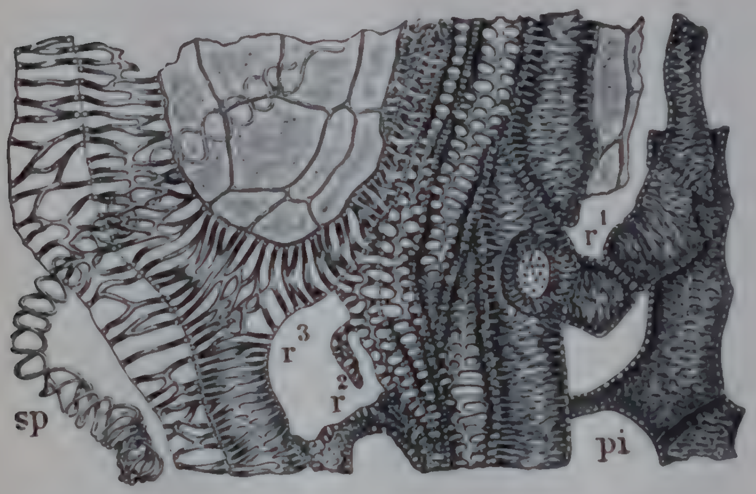

FIG. 42.—Potato. Network of vessels in tangential section. *sp* spiral vessel with two strands anastomosing at the base; *pi* pitted and r^1, r^2, and r^3 reticulated vessels. × 160. (A.L.W.)

Cavities, formed by the irregular growth of tissues, often occur in the core of the tuber. They have a dark lining due to the sclerenchymatization of the cells.

Sprouts which appear in the spring contain *starch grains* like those of the tuber but smaller. During sprouting, the grains of the tuber becomes clear and transparent and the rings indistinct. The *hairs* on the sprouts are jointed, some of the joints often being shriveled.

CHIEF STRUCTURAL CHARACTERS.—Tuber of various colors with "eyes" (leaf scars and buds). Longitudinal sections showing thin cortex, narrow bundle ring, and bulky pith with branches to the eyes.

Cork of irregularly polygonal cells; cortex and pith of isodiametric cells containing starch grains up to 100 μ (imperfect grains somewhat larger) with excentric hilum and occasional cubical crystalloids. Bundles bicollateral; vessels of various types—spiral, reticulated with wide meshes, and pitted—forming network. Cambium layer interrupted.

CHEMICAL COMPOSITION.—In the following table are results on whole potatoes compiled by Jenkins and Winton,[1] on the edible portion of potatoes, as well as boiled potatoes and potato chips (potatoes sliced and fried in deep fat), compiled by Atwater and Bryant;[2] and on evaporated potatoes by Jaffa:[3]

COMPOSITION OF AMERICAN POTATOES

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Fresh, whole (J. and W.):	12						
Min.	....	75.37	1.14	0.02	14.05	0.28	0.78
Max.	....	82.15	2.98	0.18	20.37	0.85	1.16
Aver.	....	**78.89**	**2.14**	**0.10**	**17.36**	**0.56**	**0.95**
Fresh, edible portion * (A. and B.):	136						
Min.	....	67.8	1.1	....	13.3	0.2	0.5
Max.	....	84.0	3.0	0.2	26.5	0.9	1.9
Aver.	....	**78.3**	**2.2**	**0.1**	**18.4** †		**1.0**
Evaporated (Jaffa):	3						
Min.	....	4.8	7.3	0.4	79.5		2.7
Max.	....	8.7	9.5	0.4	82.2		3.6
Aver.	....	**7.1**	**8.5**	**0.4**	**80.9**		**3.1**
Boiled, whole (A. and B.):	11						
Min.	....	69.7	1.8	0.0	16.1		0.7
Max.	....	81.0	3.1	0.4	26.5		1.4
Aver.	....	**75.5**	**2.5**	**0.1**	**20.9** ‡		**1.0**
Chips (A. and B.):	2						
Min.	....	1.8	6.0	35.5	42.7		4.5
Max.	....	2.6	7.6	44.2	50.6		4.5
Aver.	....	**2.2**	**6.8**	**39.8**	**46.7**		**4.5**

* 80 % of whole. † Fiber, 53 samples, 0.4 %. ‡ Fiber, 1 sample, 0.6 %.

Watson[4] determined solids and starch in 12 varieties, grown in states east of the Rocky Mountains, with average results respectively as follows: Connecticut 22.74 and 17.06, Indiana 18.87 and 15.13, Maine 20.18 and 15.42, Massachusetts 22.04 and 15.31, Michigan 22.17 and 14.91, North Carolina 19.98 and 15.14, Pennsylvania 20.58 and 16.01, and Virginia 23.06 and 15.62 per cent.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11**.

[2] Ibid. 1906, Bul. **28** rev.

[3] California Agr. Exp. Sta. Rep. 1898, p. 154.

[4] Virginia Agr. Exp. Sta. 1895, Bul. **56**.

Analyses of Utah potatoes, made by Cutter,[1] showed 29.58 per cent of solids and over one-third more starch than that in eastern potatoes. Widtsoe,[2] during two years, analyzed a large number of samples with results as follows: 1894, solids 19.74 to 28.12, aver. **23.39**, starch 13.98 to 22.49, aver. **17.85**; 1895, solids 15.44 to 32.47, aver. **22.06**, starch 10.17 to 23.29, aver. **16.39** per cent. Idaho also produces potatoes with high starch content and desirable baking qualities.

Colorado potatoes, as appears from the investigations of Headden,[3] instead of being midway in composition between the product of regions east of the Rocky Mountains and the Utah-Idaho region, as might be inferred from the geographical situation of the state, are even lower in starch content than those in the eastern section.

Examinations of 93 samples of potatoes from 64 localities made by Sebelien[4] permitted the following grouping by starch content: 26 samples 13.9 per cent or less, 19 samples between 14 and 15 per cent, 17 samples between 15.1 and 16 per cent, 23 samples between 16.1 and 17 per cent, and 8 samples 17 per cent or over (maximum 20.1 per cent).

Hals and Kavli[5] determined by direct analysis the usual proximate constituents, except fat, also the starch in 33 samples of Norwegian potatoes with the following average results: water 79.95, protein 1.86, starch 14.27, fiber 0.52, and ash 0.88 per cent. In addition they found by calculation 19.2 per cent of solids and 13.4 per cent of starch.

Composition of Parts of the Tuber.—Frisby and Bryant[6] separated a sample of potatoes into three parts: (1) the skin, (2) the cortex ("fibro-vascular layer"), and (3) the pith (" flesh "). By scraping the raw potato or stripping a potato boiled in its jacket, only the skin is removed, but by paring in the usual manner, as apparently carried out by these authors, a considerable part of the cortex is lost. Analyses of the parts and the whole tuber appear on the next page.

Coudon and Bussard[7] show a progressive increase in water and protein but a decrease in starch from skin to pith. Considering only the cortex and pith, their results are the reverse of those given by Frisby and Bryant.

Goldthwaite[8] confirms the results of the French authors, in that he found less water but more starch in the cortex than in the pith of the

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[1] Utah Agr. Exp. Sta. 1891, Bul. **5**.

[2] Utah Agr. Exp. Sta. Rep. 1896, p. 22.

[3] Colorado Agr. Exp. Sta. 1928, Bul. **325**.

[4] Norsk Landmansbl. 1896, **15**, 157.

[5] Tidsskr. Norske Landbr. 1903, **10**, 535.

[6] U. S. Dept. Agr., Off. Exp. Sta. 1897, Bul. **43**.

[7] Compt. rend. 1897, **125**, 43.

[8] Colorado Agr. Exp. Sta. 1925, Bul. **296**.

Composition of Whole Potato and Parts (Frisby and Bryant)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Skin	80.1	2.7	0.8	14.6		1.8
Cortex	83.2	2.3	0.1	12.6	0.7	1.1
Pith	81.1	2.0	0.1	15.7	0.3	0.8
Whole	81.3	2.0	0.1	15.7		0.9

Colorado potato. He also found that the dry matter and total carbohydrates followed the same trend as the starch. Possibly the dry Colorado atmosphere explains the lower amount of water in the outer portion of the tuber.

Relation of Specific Gravity to Starch Content.—Winton[1] and Watson[2] found that the ratio of specific gravity to starch content is not a fixed one, and more recently Matzdorff and Grossgebauer[3] reached the same conclusion; on the other hand Reichard[4] and Shutt[5] note a relationship sufficiently close for calculation of the starch content from the specific gravity.

Relation of Solids to Starch.—Märcker in a series of 55 analyses given in König's Compilation (personal contribution) shows percentages of starch derived from those of total solids by subtraction of the constant 5.8. Matzdorff and Grossgebauer[6] also employ this constant. Goldwaite[7] found that 6.7 usually was applicable for Colorado irrigated potatoes, although in some cases there was a wide variation.

Varietal Characters include composition as well as yield, form, size, and color. One desirable character may be sacrificed for another, and chemical composition, the most difficult to determine, is seldom thought of except as a measure of mealiness or other culinary properties.

The composition of certain varieties as given herewith under other heads cannot be regarded as strictly representative as other factors may exert a predominating influence.

Influence of Locality on Composition.—Whether owing to soil condition or climate, Watson[8] found that the variety Dakota Red grown in Virginia contained 9.75 per cent of starch while the same variety grown in Canada contained 14.29 per cent. A difference in climate, however,

[1] Connecticut Agr. Exp. Sta. Rep. 1887, p. 128.

[2] Loc. cit.

[3] Pharm. Zentralh. 1920, **61**, 598.

[4] Ibid. 1919, **60**, 359.

[5] Can. Dept. Agr., Dom. Chem. Rep. 1925, p. 65.

[6] Loc. cit. [7] Loc. cit. [8] Loc. cit.

can hardly be the reason why Early Rose grown in Lansing, Michigan, contained 12.38 per cent of starch while Early Rose from the same seed grown in Grand Rapids, a neighboring city, contained 15.31 per cent.

The difference in the starch content of potatoes grown in the East, in Colorado, and in Utah is unquestionably due largely to local conditions which tend to overcome all other influences affecting composition. To local conditions may also be attributed in part the unreliability of calculated results for starch when the method of calculation is based on data secured in other regions.

Seasonal Variations dependent on climatic conditions are comparatively great. Frosts, droughts, and excessive rainfall may act directly by retarding or unduly hastening development or indirectly by inducing fungous, bacterial, or other diseases.

Blomeyer,[1] who recorded the starch content in a large number of varieties during 12 years, brought out great seasonal variations in the same variety. For example, one variety contained as much as 22.7 per cent during one year and as little as 8.7 per cent during another year.

Relation of Development to Composition.—Girard[2] has studied the composition of potatoes at different stages of development from early in July to late in October. Analyses were made on two portions, the water-soluble and the water-insoluble, a procedure that might well be

COMPOSITION OF POTATOES AT DIFFERENT STAGES OF DEVELOPMENT (GIRARD)

	July 3	Aug. 4	Aug. 28	Sept. 20*	Oct. 10	Oct. 25
Aver. weight (kilos)	0.031	0.719	1.270	1.530	1.770	1.553
	%	%	%	%	%	%
Water	85.22	80.79	78.16	75.94	80.22	77.05
Soluble matter	4.72	3.87	3.34	4.60	4.67	4.60
Protein	1.36	0.91	1.19	2.06	1.99	1.98
Sucrose	1.48	1.12	0.64	0.27	0.10	0.02
Reducing sugars	0.67	0.00	0.00	0.00	0.00	0.00
Other organic matter	0.35	0.72	0.13	0.96	1.19	1.14
Ash	0.86	1.14	1.38	1.31	1.39	1.46
Insoluble matter	10.06	15.22	17.55	19.47	15.33	18.29
Protein	1.66	0.08	0.19	0.32	0.19	0.19
Starch	8.40	13.92	15.67	17.44	13.70	16.38
Fiber	....	1.23	1.60	1.60	1.31	1.66
Ash	....	0.09	0.09	0.09	0.13	0.06

* A heavy fall of rain occurred shortly after this date.

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[1] Landw. Jahrb. 1873, **2**, 178.

[2] Compt. rend. 1889, **108**, 602.

imitated in future investigations, since thereby the problem of starch determination is simplified.

It will be noted that the protein and starch content during August, when the tubers had not reached their full size, was lower than at maturity. Experiments at the Rothamstead Experiment Station in England in 1876–1878 and at the New York Agricultural Experiment Station in 1884 show that small and consequently immature potatoes contain less starch than large.

Jones and White[1] found no strongly marked difference in composition of tubers dug at different dates. In general, dry matter and nitrogen-free extract decreased while protein, ash, and crude fiber increased as the tubers approached maturity.

Rosa[2] found that the percentages of dextrose and sucrose in the underground stems are high prior to stolon formation, then diminish, and again increase when the tubers are forming. Starch, at first absent, increases rapidly with tuberization, while nitrogen decreases.

Fungous diseases that retard development of the plant also reduce the starch content, hence, as shown by Sebelien,[3] spraying with Bordeaux mixture increases the starch content of the tuber.

Influence of Methods of Culture.—Cutter[4] found that shallow planting produced tubers containing 23.1 per cent more starch than deep planting, and that close planting brought about an increase in water and a decrease in starch amounting to 7 per cent of the total quantity.

Composition of Seed and Crop.—As a part of an extensive physiological investigation involving the whole plant, Kreusler[5] analyzed large potatoes grown from large seed and small potatoes grown from small seed. Although the crop from small seed contained less starch and nitrogen-free extract and more protein on both the fresh and dry basis than that from the large, the results, some of which are tabulated on the next page, seem insufficient to warrant sweeping conclusions.

Maturing of Early and Late Dug Potatoes.—Experiments were conducted by Appleman and Miller,[6] partly to follow the process of ripening and test the validity of the claim that immature potatoes are superior for seed, but chiefly to determine the extent to which the maturing process continues during storage. In the first table herewith are results on the usual proximate constituents, also on starch, sucrose, and

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[1] Vermont Agr. Exp. Sta. Rep. 1900, p. 374.

[2] Proc. Ann. Meet. Potato Ass. America, 1924, **11**, 107.

[3] Loc. cit.

[4] Loc. cit.

[5] Landw. Jahrb. 1886, **15**, 309.

[6] J. Agr. Res. 1926, **33**, 569.

COMPOSITION OF SEED POTATOES AND CROP (KREUSLER)

	Water	Protein	Protein, pure	N_2O_5	Fat	N-f. ext.	Dextrin, etc.	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Seed:										
Large	68.82	2.72	2.00	0.002	0.03	26.59	0.42	23.83	0.60	1.24
Small	68.44	2.41	1.72	0.003	0.10	27.05	0.56	23.95	0.74	1.26
Crop:										
Large	76.69	2.66	1.79	0.004	0.05	19.13	0.00	17.14	0.56	0.91
Small	78.98	2.75	1.70	0.005	0.07	16.62	0.00	14.60	0.52	1.06

reducing sugars; in the second table are results on the distribution of the non-protein nitrogen.

COMPOSITION OF FRESH AND MATURED POTATOES DUG AT DIFFERENT STAGES (APPLEMAN AND MILLER)

Dug	Analyzed	Water	Protein	Sugars, reducing	Sucrose	Starch	Fiber	Ash
		%	%	%	%	%	%	%
June 17	June 17	83.66	1.77	0.20	0.79	10.57	0.34	0.91
June 17	Oct. 26	81.26	2.00	0.27	0.14	10.82	0.47	1.20
June 24	June 24	82.72	1.85	0.15	0.90	11.47	0.30	0.91
June 24	Oct. 26	81.78	1.88	0.28	0.12	11.68	0.43	1.10
July 8	July 8	80.80	1.82	0.11	0.56	13.80	0.32	0.91
July 8	Oct. 26	80.09	1.93	0.21	0.10	13.34	0.37	1.05
July 15	July 15	79.35	2.23	0.10	0.19	14.98	0.31	1.00
July 15	Oct. 26	78.33	2.18	0.08	0.16	14.76	0.37	1.05
July 22	July 22	80.20	2.24	0.04	0.14	14.25	0.31	1.02
July 22	Oct. 26	79.56	2.33	0.04	0.14	14.23	0.35	1.06
Aug. 27	Aug. 27	81.02	2.17	0.06	0.20	13.60	0.32	1.03
Aug. 27	Oct. 26	79.65	2.28	0.06	0.14	15.05	0.33	1.11

The authors conclude that " The ripening and maturing processes in potatoes may continue during storage, so that by the end of the rest period immature potatoes large enough for seed have practically the same composition and respiratory response as potatoes allowed to mature on the vine if both are stored under the same conditions." They further state that their results do not show any chemical or physiological basis for the claims that immature potatoes are superior for seed.

NITROGEN DISTRIBUTION OF NON-PROTEIN NITROGEN IN FRESH AND MATURE POTATOES DUG AT DIFFERENT STAGES (APPLEMAN AND MILLER)

Dug	Analyzed	Total non-protein N	N of acid amides	N in phospho-tungstic ppt.	Mono-amino N
		%	%	%	%
June 17	June 17	23.06	3.73	3.60	8.94
June 17	Oct. 26	27.42	4.23	2.10	12.10
June 24	June 24	17.84	3.40	3.09	7.34
June 24	Oct. 26	30.39	3.73	2.28	14.83
July 8	July 8	20.78	4.07	3.50	8.83
July 8	Oct. 26	32.08	4.69	2.18	15.92
July 15	July 15	22.20	4.74	3.87	11.36
July 15	Oct. 26	29.82	....	2.00	14.57
July 22	July 22	27.07	5.54	4.06	12.00
July 22	Oct. 26	35.58	7.24	2.11	18.07
Aug. 27	Aug. 27	32.18	6.58	5.49	15.05
Aug. 27	Oct. 26	31.67	5.89	2.55	15.64

Form, Color, and **Surface** of the tuber, as indicated by results obtained by Nobbe,[1] have no decided correlation with content of starch or dry matter.

Results by Hurd-Karrer and Taylor[2] show a tendency to higher protein content in small than in large tubers and in spheroidal than in elongated forms.

Influence of Fertilizers on Composition.—In general, potassium chloride tends to depress the starch content of the crop whereas potassium sulphate, potassium carbonate, mixed potassium and magnesium sulphate (" Patent Kali "), wood ashes, and calcium sulphate may or may not increase the starch content. Both sodium nitrate and ammonium sulphate appear to have a depressing action. In recent experiments by Nolte and Leonhardt,[3] Wiessmann and Schramm,[4] and Gerlach,[5] " 40% potash salts " decreased the starch content. Headden[6] has shown that nitrates may develop to such an extent in the Colorado soils as to kill the plants. The tubers from nitrate plots were watery and unpalatable.

See also Influence of Fertilizers on Solanin Content.

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[1] Landw. Vers.-Stat. 1864, **6**, 413.

[2] Plant Physiol. 1929, **4**, 393.

[3] Mitt. deut. Landw.-Ges. 1927, p. 689.

[4] Fortschritte Landw. 1928, **3**, 625.

[5] Kartoffel 1932, **12**, 78.

[6] Loc. cit.

Glassy End.—Tubers with translucent tissues at the stem end, comparable with the "water core" of apples, have been studied by Penman.[1] The tissues affected have high water and low starch content owing to withdrawal of a portion of the reserve material for second-growth tubers. Certain varieties show this tendency.

Changes During Storage; Respiration.—In experiments by Nobbe[2] light was found to exert little influence, but humidity was a more important factor, although not so important as temperature. Stored in a warm place (25 to 35° C.), whether in moist or dry air, the tubers lost moisture and gained in percentage of starch, whereas stored in a cool place, especially if in moist air, the water and starch content changed but little. Moisture and carbon dioxide were given off in the ratio of three or four to one until March when the transpiration of water doubled.

Müller-Thurgau[3] consider that the principal chemical changes taking place during storage are threefold: (1) respiratory, (2) sugar (sucrose and reducing sugars) formation from starch, and (3) starch re-formation from sugar. Respiration is favored by heat and an abundant supply of sugar. At slightly below 0° C. sugar continues to form but respiration is nearly suspended, hence the sweet taste of frozen potatoes. On the temperature being raised, starch is re-formed. The following figures, secured by Müller-Thurgau, represent quantities formed or transformed in one kilo in one hour:

	0°	3°	6°	10°	20°
	mg.	mg.	mg.	mg.	mg.
Sugars used in respiration	2.3	2.8	3.5	4.5	9.5
Sugars converted into starch	1.7	20.8	25.8	31.3	34.5
Sugars stored	28.0	9.0	4.3	...	...
Total sugars formed	32.0	32.6	33.6	35.8	44.0

Wollny[4] has supplemented the work of the foregoing investigators by experiments on a large scale and confined to the loss in weight and outward morphological changes during storage. From October to April 1 the tubers were weighed twice monthly and thereafter once a month. The loss in weight was greatest immediately after digging, then decreased until March 1, when it increased, the average losses of 12 varieties for the months beginning with October being: 2.02, 1.18, 0.50, 0.50, 0.81, 0.41, and 0.50, total 5.92 per cent, whereas thereafter the total average loss for five months was 21.57 per cent. On Nobbe's assumption that one-fourth of the loss was due to respiration, only a little less than 1.5 per cent was loss of organic matter due to Winter respiration.

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[1] J. Dept. Agr. Victoria 1929, **27**, 449.

[2] Landw. Vers.-Stat. 1865, **7**, 452.

[3] Landw. Jahrb. 1882, **11**, 751; 1885, **14**, 851.

[4] Forsch. Geb. agr. Physik. 1891, **14**, 286.

Appleman[1] has conducted experiments on the relation of starch and sugar transformation, respiratory changes, loss in weight, and the effects of sprouting. Below +4° C., sugars formed from starch were found to accumulate, the rate of accumulation being most rapid between −1.5 and +0.5° C., the maximum of 3 to 4 per cent being reached in four to six weeks. Freezing does not begin until between −2 and −3° C. Four-fifths of the sugars thus accumulated again pass into starch during storage of the tubers for a week at +21 to +24° C., the remaining fifth representing loss through respiration. Most of the sugars will disappear after storing three to four weeks at +7.5 to +10.5° C. Confirming the results of earlier investigators, the author found that respiration goes on continuously in stored potatoes, increasing within certain limits with a rise in temperature and nearly ceasing at just above the freezing point. An accumulation of sugars, germination, and moist air accelerate the rate. The heating of potatoes in large heaps is due to high respiration and poor ventilation. Storage at just above freezing is best for seed potatoes, at 4 to 6° C. for cooking potatoes.

Later studies of the rest period (" after ripening ") by Appleman[2] show that the changes that take place are dependent solely on temperature involving respiration and transpiration and do not affect materially the nitrogenous and phosphorus-organic matter, the lipoids, etc., since there is no gradual increase of diastatic, proteolitic, or other enzyme activity. It is at the sprouting period that profound changes take place.

Schulz[3] found that tubers of late varieties respire more rapidly than those of early varieties, although there was considerable variation in individual tubers. The rate was fairly uniform for three months and bore no apparent relation to the size of the tubers and number of sprouts that formed.

The sugar content of potatoes, as determined by Wright,[4] increased with the decrease in storage temperature from 5 to 0° C. (40 to 32° F.) and decreased with the increase of the temperature above 5° C. The rate of respiration decreased with the time of storage.

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[1] Maryland Agr. Exp. Sta. 1912, Bul. **167**, 327.

[2] Science 1914, **39**, 294; Bot. Gaz. 1916, **61**, 265.

[3] Landw. Vers.-Stat. 1926, **105**, 23.

[4] J. Agr. Res. 1932, **45**, 543.

Losses on Boiling.—Independent experiments by Snyder and by Frisby and Bryant made in cooperation with the U. S. Department of Agriculture[1] show that potatoes, even after peeling, lose little on boiling, compared with such vegetables as cabbage and carrots. If cooked without peeling, this loss may be reduced to an insignificant amount.

Losses on Boiling Potatoes

(Parts per 100 of each nutrient)

	Solids	Nitrogen			Carbohydrates	Ash
		Total	Protein	Non-protein		
	%	%	%	%	%	%
Snyder:						
Peeled:						
Water cold at start*.	6.5	51.8	....	....	....	38.3
Water cold at start..	3.1	15.8	....	....	1.0†	18.3
Water hot at start...	3.4	8.2	....	....	1.0†	18.1
Not peeled:						
Water cold at start..	0.4	1.0	....	....	0.1†	3.4
Water hot at start...	0.4	1.0	....	....	0.1†	3.3
Frisby and Bryant:						
Peeled:						
Water cold at start..	3.7	8.3	4.3	12.9	2.5	17.0
Water hot at start...	4.0	10.0	3.3	17.9	2.8	17.4
Not peeled:						
Water cold at start..	0.3	0.6	0.6	0.6	0.2	1.9
Water hot at start...	0.3	1.0	0.4	1.7	0.1	1.2

* Soaked before boiling. † Starch.

Relation of Composition to Cooking Qualities.—Experiments with 10 varieties by Von Gözsy and Mészáros[2] led to the conclusion that tubers with low starch and high protein content have the best flavor and keeping qualities but brought out no correlation between composition and disintegration during boiling or fat absorption during frying.

F. T. McLean[3] states that watery tubers of low starch content are preferred for the manufacture of commercial potato chips.

Sweetman[4] states that superior mealiness is not attributable to any single factor, although high starch content is correlated with inferior mealiness.

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[1] Off. Exp. Sta. 1897, Bul. **43**.

[2] Z. Unters. Lebens. 1931, **61**, 174.

[3] Personal communication.

[4] Maine Agr. Exp. Sta. 1931, Bul. **360**, 194.

Proteins.—According to Osborne and Campbell,[1] the juice of the tuber contains the greater part of the proteins consisting of a globulin, *tuberin*, and a very small amount of a *proteose*. The tuberin, being soluble in very dilute salt solution, is precipitated incompletely and with difficulty by dialysis. Thus prepared, it changes to a large extent into a modification much more insoluble in salt solution. Alcohol quickly brings about the same change. A solution of tuberin in 10 per cent salt solution generally coagulates in part at 60 to 65° C. but not completely until heated for some time at 80° C.

The *Ultimate Composition of Tuberin*, as found by the above-named authors, follows:

	%
Carbon	53.61
Hydrogen	6.85
Nitrogen	16.24
Sulphur	1.25
Oxygen	22.05
	100.00

The *Amino Acids of Tuberin*, as separated by Sjollema and Rinkes[2] following Fischer's method, were present in the following amounts:

PRODUCTS OF HYDROLYSIS OF TUBERIN (SJOLLEMA AND RINKES)

	%
Alanine	4.9
Valine	1.1
Leucine	12.2
Cystine	4.4
Glutamic acid	4.6
Tyrosine	4.3
Phenylalanine	3.9
Proline	3.0
Arginine	4.2
Lysine	3.3
Histidine	2.3
Ammonia	1.8
	50.0

The authors further report valine and alanine together 8.2 per cent, also valine and leucine together 1.9 per cent. No attempt was made to determine tryptophane, serine, and hydroxyproline.

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[1] J. Am. Chem. Soc. 1896, **18**, 575.

[2] Z. physiol. Chem. 1911–12, **76**, 369.

In potato protein Fürth and Lieben[1] found *tryptophane* 3.3 per cent.

Free Amino Acids.—Schulze[2] demonstrated the presence of *histidine*, *lysine*, and *arginine* in potato juice; these are also present in etiolated shoots.

Tyrosine also occurs in potato juice. The darkening of cut surfaces of the tuber is due to the formation of *melanin* through the action of the enzyme *tyrosinase* on tyrosine. Haehn[3] groups different varieties according to the melanin-number as determined by titration with potassium permanganate solution. His further investigations led him to believe that melanin formation proceeds in stages and that tyrosinase is a mixture of several enzymes among which are a phenolase, an amino-acidase, and an unknown condensing enzyme.

McIntosh,[4] as a means of distinguishing varieties, uses the tyrosine reaction employing a slightly alkaline solution of *p*-cresol, the melanin test as measured by the blackening of slices, the oxidase test employing benzidine, and the alkali test depending on the yellow color due to flavones. Lauder and Robertson[5] employ a modification of the *p*-cresol test and claim that its reliability, when applied to sound, whole tubers, is not seriously influenced by locality of growth, reaction of soil, seasonal variations, or storage.

Porphyrin.—According to Fischer and Schwerdtel,[6] porphyrin is present in potatoes.

Acids.—As determined by Arbenz,[7] 0.04 per cent of *oxalic acid* is present.

Results by Robertson and Smith[8] show that the hydrogen-ion concentration increases with growth. During the early stages it is greatest at the stem end, during the resting stage it is quite uniformly distributed, during sprouting it increases at the eyes.

Carbohydrates.—Many results on *starch* and *sugars* are included under the foregoing heads.

Nelson and Auchincloss[9] disagree with earlier investigators who considered dehydration of potato slices essential for increasing the sucrose content. They present evidence that sucrose in the tuber is synthesized from dextrose and levulose, not directly from starch, also that oxygen is necessary for the formation of sucrose in potato slices.

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[1] Biochem. Z. 1921, **122**, 58.

[2] Landw. Vers.-Stat. 1904, **59**, 331.

[3] Z. Spiritusind. 1920, **43**, 90, 104, 111.

[4] Scottish J. Agr. 1928, **11**, 304; 1931, **14**, 47.

[5] Ibid. 1931, **14**, 47.

[6] Z. physiol. Chem. 1926, **159**, 120.

[7] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[8] Biochem. J. 1931, **25**, 763.

[9] J. Am. Chem. Soc. 1933, **55**, 3769.

Pectins.—According to Dastur and Agnihotri[1] all forms of pectin increase during growth, but the middle lamella pectin, which forms about 80 per cent of the total pectin during the early stages, is somewhat diminished at maturity. Free soluble pectin, which previously was present in small amount, is formed during storage at the expense of protopectin and middle lamella pectins, and probably is itself decomposed forming pectic acid.

Glucosides. *Solanin.*—This glucoside, also classed as an alkaloid, as shown by early investigators exists not only in the potato tuber but also in other parts of the potato plant and in the fruit of other solanaceous species. There is a conflict of evidence as to its composition, its origin, the amount in the tuber, and its toxicity. There may be several solanins.

The following widely differing formulas have been assigned to solanin:

$C_{52}H_{93}NO_{18} + 4\frac{1}{2}H_2O$ (Firbas).[2]
$C_{28}H_{47}NO_{10} + 2H_2O$ (Cazeneuve and Breteau).[3]
$C_{43}H_{75}NO_{15}$ (various authors).
$C_{32}H_{51}NO_{11}$ (Colombano).[4]

As prepared by Cazeneuve and Breteau from potato sprouts, it forms colorless needles melting at 250° C. It has a bitter taste, is weakly alkaline and soluble in hot alcohol but nearly insoluble in water and most organic solvents, amyl alcohol excepted. Warmed with dilute acid, it splits up into solanidin and sugars, but the exact nature of the reaction is not fully understood. Rhamnose and galactose or else rhamnose and glucose appear to be formed.

Solanidin resembles solanin in appearance and properties. Firbas assigned to it the formula $C_{40}H_{61}NO_2$, but other formulas ($C_{28}H_{41}NO_2$, etc.) have been suggested. The melting point commonly given is 191° C.; that found by Colombano is 210 to 215° C. Colombano states that the solanidin from the berries of *Solanum sodomæum* melts at 190 to 192° C.

Solanein ($C_{52}H_{83}NO_{13} + 3\frac{3}{4}H_2O$) was found by Firbas to accompany solanin in potatoes. It is separated from the latter by recrystallization from 85 per cent alcohol in which it is more readily soluble. It melts at 208° C. and is decomposed by dilute acid into solanidin and sugar.

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[1] Indian J. Agr. Sci. 1934, **4**, 430.
[2] Monatsh. Chem. 1889, **10**, 541.
[3] Compt. rend. 1899, **128**, 887.
[4] Gaz. chim. ital. 1908, **38** I, 19.

Solanin Content of Potatoes.—Baup[1] early found solanin in potato sprouts, and Spazier[2] in potatoes. Bach[3] showed that the outer portion of the tuber contains more than the inner and the sprouts more than the tuber. It is frequently stated that 70 per cent is removed in the parings.

The figures in the literature vary greatly. Passing over earlier results, Bömer and Mattis[4] give 20 to 89 mg. per kilo as the range for normal potatoes of the 1922 and 1923 crops and 277 to 583 for abnormal potatoes of the 1922 crop which had caused poisoning. They consider potatoes containing over 200 mg. per kilo as unfit for food. Peeled potatoes lose part of the solanin on boiling, but unpeeled potatoes lose none. Griebel[5] found in one sample 790 mg. per kilo of solanin before and 555 after peeling. In one region of Germany, according to Alfa and Heyl,[6] the solanin content of the abnormal 1922 crop ranged from 100 to 400 mg. per kilo.

Schowalter and Hartmann[7] found that on storage the 1922 crop showed in the parings an average increase from 99.5 to 243.2 mg. per kilo, in the interior part a decrease from 225.5 to 172.8, and in the whole potatoes a slight increase. The sprouts contained over twice as much as the tuber. Hansen[8] found 1.44 per cent in dried sprouts, 0.115 per cent in dried skins of raw potatoes, and 0.165 per cent in dried skins from cooked potatoes.

In tests by Morgenstern,[9] table potatoes on an average contained 125 and feeding potatoes 58 mg. per kilo of solanin; also red varieties (8 samples) contained 119 and yellow varieties (13 samples) 78 mg. per kilo. It was further learned that unripe tubers contained more solanin than ripe and that the formation of the green color on exposure to light was accompanied by a marked increase in solanin. This latter point is not, however, in harmony with the view of Schowalter and Hartmann.

In the crop of the early variety *Vater Rhein* dug in late September,

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[1] Berz. Jahrb. 1827, **6**, 259.

[2] Schweigger J. 1831, **61**, 311.

[3] J. prakt. Chem. 1873, **7**, 248.

[4] Z. Unters. Nahr.-Genussm. 1924, **47**, 97.

[5] Ibid. 1923, **45**, 175.

[6] Ibid. 1923, **46**, 306.

[7] Ibid. 1924, **47**, 251.

[8] Exprtl. Path. Ther. 1919, **20**, 385.

[9] Landw. Vers.-Stat. 1907, **65**, 301.

Valentin[1] found by three methods an average of 448 mg. per kilo of solanin, whereas in wintered seed-tubers only about one-tenth that amount was present.

Influence of Fertilizers on Solanin Content.—Morgenstern[2] found that humus, moisture, and potash tend to diminish, whereas phosphoric acid and nitrogen increase, the amount slightly. Schowalter and Hartmann[3] were unable to detect any correlation between fertilizer and solanin content. Sabalitschka and Jungermann[4] found that nitrogen had little effect, whereas, contrary to Morgenstern's experience, potash caused a marked increase of solanin.

Toxic Effects of Solanin.—As shown by Schmiedeberg and others, solanin is unquestionably a toxic substance, but there is a diversity of opinion as to whether the amounts normally present are injurious to health and whether the epidemics of potato poisoning are attributable to it.

Weil[5] concludes that solanin is formed by bacteria but is itself responsible for potato poisoning. Bömer and Mattis[6] and others also conclude that high solanin content is the cause of certain epidemics. Droste,[7] on the other hand, believes that cases of poisoning can usually be attributed to toxins, other than solanin, formed by yeast and bacteria. Wintgen[8] asserts that less solanin is present in potatoes than is usually believed, and that no more is present in diseased than in sound potatoes. He was unable to confirm Weil's conclusion that solanin is formed by bacteria. Hansen[9] attributes the cause of the epidemics to certain bacterial toxins and believes that solanin is harmless because it is hydrolyzed in the stomach to solanidin, which is insoluble.

It seems folly on the one hand to question that solanin itself is toxic and on the other hand to saddle the blame for all cases of alleged potato poisoning on solanin without further investigation including quantitative determinations. When potatoes form the chief article of diet, as often is true in continental Europe where the individual may consume a kilogram or more a day, an abnormal amount of solanin would doubtless be objectionable if not dangerous, but when the diet is well diversified and the potatoes are sound and normal there seems no occasion for alarm. A food so largely used should be carefully guarded, however, and the points in dispute permanently settled by careful investigation.

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[1] Pharm. Zentralh. 1933, **74**, 611.

[2] Loc. cit.

[3] Loc. cit.

[4] Pharm. Ztg. 1925, **70**, 272.

[5] Arch. Pharm. 1906, **245**, 70; Pharm. Ztg. 1925, **70**, 1145.

[6] Loc. cit.

[7] Pharm. Zentralh. 1915, **65**, 311.

[8] Arch. Pharm. 1906, **244**, 360.

[9] Loc. cit.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[1] reports in the tuber 1.70 per cent, dry basis.

Enzymes. *Tyrosinase.*—See Amino Acids above. The tyrosinase activity, as determined by Robertson,[2] varies with variety and maturity but not with the size, season, environment, and kind of storage.

Amylase.—Bodnar[3] found that with the increased activity of the amylase the amount of total sugars and sucrose increased, except in certain cases where more active respiration unduly diminished the sugars. Haehn and Schweigart[4] note that sodium fluoride, sodium chloride, calcium chloride, glycine, alanine, and leucine activate the amylolytic action of potato juice, while asparagine and glutamic acid are unfavorable. Doby and Burger[5] give pH 6.95 to 7.0 as the optimum for amylase. Freshly dug tubers show pH 5.8 to 5.9, increasing in a few weeks to 6.4 with an increase of severalfold in saccharifying power. Rivière and Bailhache[6] demonstrated that potatoes attacked by *Phytophthora infestans,* owing to the action of *diastases* secreted by the mycelium, contained 85 per cent of dextrose, whereas sound potatoes contained only 40 per cent.

Oxydase.—Bunzel[7] measures quantitatively the oxydase of potatoes, employing pyrogallol to absorb oxygen through the agency of the juice. The carbon dioxide formed is determined by sodium hydroxide and the oxygen absorbed by means of a manometer.

Catalase.—Tests by Klinkowski[8] brought out a greater amount of catalase in the skin than in the inner tissues. Bunzell and Kenyon[9] find less catalase in the tubers than in the foliage, where it is most abundant at the middle period of growth.

Polyphenoloxidase and a catechol derivative, oxidizing to quinone when the tissues are injured, are stated by Szent-Györgyi and Vietorisz[10] to occur in the tuber. With the proteins or amino acids, quinone forms dark-colored products.

An *oxidoreductase* present in the potato has been shown by Michlin and Severin[1] to be an aldehydrase reducing nitrate to nitrite in the presence of an aldehyde but not capable of changing aldehyde to alcohol.

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[1] Philippine Agr. 1932, **21**, 53.

[2] Proc. Roy. Soc. Edinburgh 1932, **52,** III, 309.

[3] Bul. Agr. Sta. Hungary 1915, **18**, 789.

[4] Biochem. Z. 1923, **143**, 516.

[5] Fermentforsch. 1932, **13**, 209.

[6] J. soc. nat. hort. France, 1909, IV, **10**, 349.

[7] U. S. Dept. Agr., Bur. Plant Ind. 1912, Bul. **238**.

[8] Arb. biol. Reichs. Landw.-Forstw. Berlin-Dahlem 1932, **20**, 91.

[9] Bul. Tor. Bot. Club. 1933, **60**, 469.

[10] Biochem. Z. 1931, **233**, 236.

Mineral Constituents.—Numerous analyses of the ash of the potato have been made by early and recent investigators. The average of 3 early analyses by Way and Ogston[2] and of 40 analyses compiled by Atwater and Bryant[3] appear below:

COMPOSITION OF POTATO ASH

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
W. and O.......	59.5	2.2	4.0	5.1	1.3	18.5	3.0	3.9	2.8
A. and B.......	59.2	4.0	1.0	4.5	......	13.8	6.5	......	......

Compared with analyses reported by Wolff, the percentages of soda, as given by Atwater and Bryant, are high, while those for lime and phosphoric acid are low. The figures for iron given in early analyses are usually much too high, and those for sand and silica have little significance since they are dependent on the care taken in cleaning the tubers.

Minor Mineral Constituents. *Iron.*—Tuber, peeled, 12 mg. per kilo, fresh basis (Sherman).[4] Tuber, whole, 14 mg. per kilo, fresh basis (Bunge quoted by Sherman).[4] Tuber, whole, 19 samples, 65 to 185, aver. **99** mg. per kilo, dry basis (Remington and Shiver).[5] Tuber 8.5 mg. per kilo, fresh basis (Peterson and Elvehjem).[6] Tuber, 2 samples, 6.5, 7.3 mg. per kilo, fresh basis (Toscani and Reznikoff).[7]

Blunt and Otis[8] found that the loss of iron on boiling potatoes amounted to 22 per cent of the whole.

Aluminum.—Tuber 76 mg. per kilo, dry basis (Bertrand and Lévy).[9] Tuber 9.7 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[10]

Manganese.—Tuber, whole, 8.5 to 19.1, aver. **14** mg. per kilo, dry basis (Bode and Hembd).[11] Tuber, whole 1.84, parings (5 per cent of tuber) 1.90 mg. per kilo, dry basis (Quartaroli).[12] Tuber, whole, 39 samples, 5.6 to 14.3, aver. **9.4** mg. per kilo, dry basis (Remington and Shiver).[5]

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[1] Biochem. Z. 1931, **237**, 339.

[2] Johnson: How Crops Grow, New York, 1903, p. 168.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[4] Ibid. 1907, Bul. **185**.

[5] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[6] J. Biol. Chem. 1928, **78**, 215.

[7] J. Nutrition 1934, **7**, 79.

[8] J. Home Econ. 1917, **9**, 213.

[9] Compt. rend. 1931, **192**, 525.

[10] Am. J. Physiol. 1929, **90**, 72.

[11] Biochem. Z. 1921, **124**, 84.

[12] Ann. chim. appl. 1928, **18**, 47.

Copper.—Tuber, 1.9 mg. per kilo, fresh basis, 7.7 mg. per kilo, dry basis (Guérithault).[1] Tuber 4 to 6 mg. per kilo, dry basis (Maquenne and Demoussy).[2] Tuber, whole 10, parings 15.1 mg. per kilo, dry basis (Quartaroli).[3] Tuber, whole, 43 samples, 3.8 to 19.6, aver. **7.4** mg. per kilo, dry basis (Remington and Shiver).[4] Tuber, sprayed 30, unsprayed 18; skin, sprayed 14, unsprayed 21; sprouts, sprayed 41 mg. per kilo, dry basis (Cook).[5] Tuber 6.5 mg. per kilo (Satterfield and Jones).[6] Tuber 1.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

Zinc.—Young tuber 2, full-grown red tuber 4 mg. per kilo, fresh basis (Bertrand and Benzon).[8]

Arsenic.—Tuber 0.08 mg. per kilo, fresh basis (Jadin and Astruc).[9]

Iodine.—Present (Winterstein).[10] Tuber, 135 samples grown in Pennsylvania, 0.01 to 0.22, aver. **0.08** mg. per kilo, dry basis; slightly more in glaciated than in non-glaciated regions; no correlation with fertilization, size of tuber, variety, and the occurrence of goiter in region of growth was established (Frear).[11]

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[1] Compt. rend. 1920, **171**, 196.
[2] Ibid. 1920, **170**, 87.
[3] Loc. cit.
[4] Loc. cit.
[5] J. Agr. Res. 1921, **20**, 623.
[6] J. Elisha Mitchell Sci. Soc. 1932, **48**, 16.
[7] J. Biol. Chem. 1929, **82**, 465.
[8] Bul. soc. hyg. aliment. 1928, **16**, 457.
[9] Compt. rend. 1912, **155**, 291.
[10] Z. physiol. Chem. 1918, **104**, 54.
[11] J. Agr. Res. 1934, **48**, 171.

TUBERS OF THE COMPOSITE FAMILY

(*Compositæ*)

THE Jerusalem artichoke, like the common roots of the family, is rich in *inulin*. Special cells contain *oleoresin*.

JERUSALEM ARTICHOKE

Helianthus Tuberosus L.

Fr. Topinambour. Sp. Girasol. It. Girasole de Canada.
Ger. Topinambour.

Gray states that this species occurs wild in the United States from New York to Minnesota and southward. It is said that the American Indians grew the plant for its edible tubers before the advent of Europeans. It is now cultivated in both Europe and America, the tubers being used as food for man and cattle. The crop is easily grown and the yield is large. Swine are particularly partial to the tubers and delight in rooting them out of the ground.

The commercial production of levulose and levulose syrup from Jerusalem artichokes has recently been given attention by Golovin[1] in Russia, McGlumphy[2] in Iowa, Dykins[3] in Illinois, and their associates.

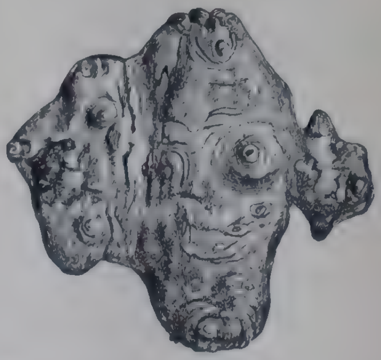

FIG. 43.—Jerusalem Artichoke. Tuber. × ½. (A.L.W.)

MACROSCOPIC STRUCTURE.—The *tubers* (Fig. 43) are irregular in shape, on account of the swollen warty eyes, and are further marked by transverse wrinkles formed by the leaf sheaths. The flesh varies in color from white to orange. In most parts the cambium layer is only 1 to 2 mm. from the surface.

MICROSCOPIC STRUCTURE.—As is true of all composite roots, inulin is present throughout the tissues. Owing to the warts and wrinkles the arrangement of the tissues is much distorted.

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[1] J. Sugar Ind. (U.S.S.R.) 1929, **3**, 140.

[2] Ind. Eng. Chem. 1931, **23**, 1202.

[3] Ibid. 1933, **25**, 937, 1165.

Cork.—Polygonal cells, tending toward quadrilateral, of a yellow-brown color, form one or more outer layers, but the typical arrangement one above another is not well marked.

Cortex.—In tangential section, the cells are polygonal or quadrilateral; in cross section, they are isodiametric, rounded, increasing in size inward. Moeller[1] draws some of the cells with thickened and sclerenchymatized walls; in our specimens, however, only impregnation of the walls with resinous matter was noted. *Oleoresin ducts* with bright yellow, solid contents are conspicuous; typical latex tubes are not evident.

Phloem.—*Sieve tubes* and *companion cells* of the primary bundles are particularly well marked in cross sections, owing to the refraction of the swollen walls. *Oleoresin ducts* are numerous.

Cambium.—Well marked.

Xylem.—The *vessels* are especially numerous near the cambium zone, although in the primary bundles they extend well inward. They are for the most part spiral or spiral-reticulated, up to 30 μ broad. *Parenchyma* of the bundle rays and medullary rays is not easily distinguished in cross section, being in both parts in well-marked radial rows. In longitudinal section, the cells of the *xylem parenchyma* about the vessels are longitudinally elongated, whereas those of the medullary rays are more often radially elongated.

Pith.—The cells in the outer part, as in the xylem zone, are in radial rows which gradually change toward the center where the cells are in longitudinal rows.

Chief Structural Characters.—Tubers warty and wrinkled; flesh white to orange; cambium zone near the surface.

Cork yellow-brown, not well marked. Cortex cells isodiametric, increasing in size inward; oleoresin ducts with bright yellow contents. Sieve tubes of the phloem distinct. Vessels mostly spiral or spiral-reticulated, up to 30 μ broad; xylem and pith parenchyma in striking radial rows changing toward center to longitudinal. Inulin present throughout the tissues.

CHEMICAL COMPOSITION.—The Jerusalem artichoke is of particular interest because the nitrogen-free extract is largely inulin which in the opinion of some authorities renders it of value as a diabetic food.

The analyses in the following table are on the authority of Kornauth,[2] Strauss,[3] Langworthy,[4] Hemmi,[5] Müntz and Girard, quoted by Traub et al.,[1] Shohl,[2] Shutt,[3] and Traub, Thor, Zeleny, and Willaman[1]:

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[1] Mikroskopie Nahrungs-Genussmittel, Berlin, 2. Aufl. 1905, p. 559.

[2] Z. landw. Versuchsw. 1910, **13**, 261.

[3] Berl. klin. Wochschr. 1912, **49**, 1213.

[4] U. S. Dept. Agr. 1917, Bul. **468**.

[5] J. Col. Agr. Hokkaido Imp. Univ. 1918, **8**, 33.

COMPOSITION OF JERUSALEM ARTICHOKES

	Water	Protein	Fat	N-f. ext.	Sugars	Inulin	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Kornauth...	00.00	15.00	0.66	75.40	....	59.40	......	3.35	5.50
Strauss.....	72.62	1.97*	......	13.08†	....	....	......	......	1.89
Langworthy	78.70	2.50	0.20	16.70	....	....	......	0.80	1.10
Hemmi.....	82.27	2.31‡	0.14	13.28§	2.15‖	6.51	0.79	0.88	1.12
M. and G...	81.90	2.46	......	....	11.05		0.83	......	1.50
Shohl......	79.00	3.10¶	0.20	....	15.50**		......	0.80	1.10
Shutt......	73.23	2.33	0.13	21.46	....	....	......	1.23	1.62
Traub et al.	79.80	2.56	......	....	15.04**		0.83	......	1.08

* Pure protein 0.81%. † Includes fiber. ‡ Pure protein 1.25%. § Galactan 0.58%. ‖ Reducing sugars 0.41%, non-reducing sugars 1.74%. ¶ Pure protein 0.90%. ** Water-soluble carbohydrates.

Analyses by Behrend[4] summarized below show the composition of 7 samples of the tuber in Fall and Spring, on the fresh basis. Calculated to the water-free basis the averages show that during the Winter there was a slight loss of protein and ash, and a slight gain in the different carbohydrates—sugars, pentosans, and fiber. The range in composition was, however, too great to warrant sweeping conclusions. The figures are of interest as showing the amounts in this vegetable of pentosans, also of the sugars formed by hydrolysis which represent largely inulin in the Fall but, as shown by later investigators, are changed during the Winter.

Carbohydrates.—Corroborating results by Dubrunfaut obtained in 1867, H. Colin[5] states that juice of the Jerusalem artichoke is strongly levorotatory in October owing to an accumulation of *inulin* but dextrorotatory in March. *Sucrose* is always present but the amount increases during the Winter. The juice of the stored tuber polarized +10 direct and −55° inverted, showing that levorotatory substances ("levulosans") are present.

Colin in a later paper[6] concludes, from analyses made at different

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[1] J. Agr. Res. 1929, **39**, 551.

[2] J. Am. Chem. Soc. 1923, **45**, 2754.

[3] Canada Dept. Agr., Dom. Chem. Rep. 1927, p. 53.

[4] J. Landw. 1904, **52**, 127.

[5] Compt. rend. 1918, **166**, 305.

[6] Rev. gén. botan. 1919, **31**, 70, 179, 229, 277.

Composition of Jerusalem Artichoke Tubers in Fall and Spring (Behrend)

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sugars, direct*	Sugars, inverted*	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Fall:										
Min...	75.00	1.06	0.60	0.09	14.69	....	11.37	0.77	0.54	0.88
Max..	81.80	1.88	1.09	0.18	21.26	0.66	17.12	1.21	0.90	1.18
Aver..	**79.70**	**1.48**	**0.88**	**0.14**	**16.93**	**0.15**	**13.32**	**0.91**	**0.68**	**1.08**
Spring:										
Min...	75.88	0.77	0.52	0.14	12.17	0.35	9.23	0.91	0.66	0.78
Max..	83.93	1.93	1.09	0.32	20.59	1.35	16.76	1.39	0.90	1.21
Aver..	**79.03**	**1.27**	**0.79**	**0.18**	**17.76**	**0.67**	**14.04**	**1.18**	**0.77**	**0.99**

* As dextrose.

stages of development, that the leaves of inulin-containing composites synthesize *reducing sugars*, mostly levorotatory, which are condensed in the stem to inulin and stored in the root. Young and ripe artichoke tubers are practically the same in composition. During the Winter reducing sugars are reformed from inulin. Germination is accompanied by a change of inulin, as well as other levulosans and sucrose, into reducing sugars which migrate toward the stem.

Inulin.—The formula $(C_6H_{10}O_5)_n$ applies to inulin as well as starch, the value for n being variously stated as 6, 12, and 30, or approximately these figures. It forms sphæro-crystals containing one molecule of water to each molecule of $C_6H_{10}O_5$. The solid substance is hygroscopic, tasteless, with a melting point of about 165° C., and a specific rotation $[\alpha]_D$ of about -38. It does not reduce Fehling solution, but is hydrolyzed to levulose by acids and the enzyme *inulase* formed in sprouting tubers.

It is particularly abundant in the roots and tubers of the sunflower family (*Compositæ*). In addition to the tubers of the Jerusalem artichoke and dahlia, it is the chief carbohydrate in the roots of elecampane (*Inula Helenium*), dandelion, chicory, and salsify, from which it may be prepared, taking advantage of its solubility in water and 40 to 50 per cent alcohol, the latter precipitating mucilaginous substances, and its insolubility in strong alcohol.

Hemicellulose.—Hemmi[1] found that the hemicellulose of the tubers yielded on hydrolysis *l*-arabinose and *d*-galactose.

Mineral Constituents.—Haskins[2] reports potash 0.48 and phosphoric acid 0.17 per cent in the tubers but does not give the percentage of ash. Dunton[1] found: water 81.2, ash 1.26, calcium 0.0227 (CaO 0.031), phosphorus 0.0992 (P_2O_5 0.23) per cent. The relatively high phosphorus and iron and the low calcium content are noted by Dunton.

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[1] Loc. cit.

[2] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul., p. 91.

Minor Mineral Constituents. *Iron.*—Tuber 34 mg. per kilo, fresh basis (Dunton).[2]

Aluminum.—Tuber 24.6 mg. per kilo, dry basis (Bertrand and Lévy).[3]

Zinc.—Tuber 2.8 mg. per kilo, fresh basis (Bertrand and Benzon).[4]

[1] Forecast 1927, **34**, 295, 332.

[2] Loc. cit.

[3] Bul. soc. hyg. aliment. 1931, **19**, 359.

[4] Ibid. 1928, **16**, 457.

LEAF AND STEM VEGETABLES

GREAT numbers of species are used as stem and leaf vegetables but many of these are of local importance. In the temperate zone the salad vegetables and others eaten raw belong mostly in the *Compositæ* and *Umbelliferæ*, the pot greens mostly in the *Cruciferæ* and *Chenopodiaceæ*. Members of the onion group are sometimes classed as roots, but the part eaten is fleshy leaf tissues, hence they are grouped in this section.

MACROSCOPIC STRUCTURE.—The parts of stem and leaf vegetables are conveniently grouped as (1) *stem*, (2) *petiole*, and (3) *leaf blade.* The ribs and veins of the leaves partake of the general characters of the petiole, but the dark green intervenal tissue is very different.

MICROSCOPIC STRUCTURE.—**Stems** of typical edible vegetables consist of (1) *epiderm* of usually elongated cells and sometimes also stomata and hairs, (2) *hypoderm* of collenchyma cells often forming an interrupted layer, (3) *cortex*, (4) *central cylinder*, and (5) *pith*. In monocotyledons the fibro-vascular bundles are distributed at intervals in the parenchymatous ground tissues, whereas in dicotyledons the phloem, cambium, and xylem form concentric rings about the stems.

Petioles differ from stems in their histological structure chiefly in being bilateral.

Leaf Blades are characterized by the intervenal tissue which in its simplest form consists of two *epiderms*—the outer or lower and the inner or upper—with *chlorophyl parenchyma* between. Stomata are usually present in different proportions in the two epiderms, being usually fewer in the inner than in the outer. Hairs of different types may occur on one or both. The chlorophyl parenchyma adjoining the inner epiderm consists of more or less pronounced palisade cells, whereas that adjoining the outer epiderm, at least beneath and in the vicinity of the stomata, consists of loosely arranged cells, thus facilitating the exchange of gases during photosynthesis, respiration, and transpiration. *Chlorophyl grains* occur in great numbers in leaves exposed to sunlight; in blanched leaves these are not present.

Calcium oxalate *crystals* are of frequent occurrence. For example, crystal rosettes are found in rhubarb and New Zealand spinach, prismatic crystals in the onion group, raphides in the palm and asparagus, and crystal sand in the beet group.

Examples of constituents characterizing families are the *oleoresin* of umbelliferous plants and the *latex* of composite plants, each in appropriate passages. Red or purple *coloring matter* of the anthocyanin group is present in solution in the epidermal or subepidermal cells of red cabbage and the petioles and ribs of beet leaves.

Reserve starch does not occur in aerial parts but is present in the swollen scales—morphologically leaves—of the Chinese lily bulb.

CHEMICAL COMPOSITION.—Leaves and stems, calculated to the dry basis, show commonly higher percentages of protein, fat (ether extract), fiber, and ash, but lower percentages of nitrogen-free extract (carbohydrates) than most other vegetables whether flower, fruit, seed, or root. These constituents, however, determined by the usual methods, are cruder than those of seeds. Growing shoots are rich in asparagin and other amides, hence the use of the factor 6.25 in calculating protein from the nitrogen gives a figure higher than the truth. Ether extract, which in seeds is largely fat, in leaves is to a very large extent chlorophyl, wax, or other ether-soluble substances unlike fat in nutritive value. Again fiber, always " crude," is especially so in the case of vegetables, the young tissues of which have cell walls easily acted on by the acid and alkali used in the determination. Still again the ash of leaves and stems contains a considerable amount of carbon dioxide formed during the burning, which replaces organic radicals. Figures for nitrogen-free extract, obtained by difference, obviously are influenced by errors of the direct determinations. Included in the nitrogen-free extract are organic acids which are evident to the taste in rhubarb petioles and sorrel, also in some other leaves, and are present as salts in these and other vegetables not distinctly sour.

There is perhaps no other class of foods, except possibly roots, the composition of which is so imperfectly understood. Patient investigation with due recognition of the relation of structure to composition will certainly enlarge our horizon.

PETIOLES OF THE POLYPODY FAMILY

(*Polypodiaceæ*)

VARIOUS species of ferns have edible shoots or rhizomes; the common brake, a cosmopolitan plant, yields both.

BRAKE

Pteridium aquilinum Kuhn.

Fr. Fougère commune. Sp. Helecho. It. Felceto. Ger. Adlerfarn. Jap. Warabi.

Petioles of the brake are a common food in Japan and China, also in Hawaii where there is a large oriental population. Although in the United States they are not generally recognized by the native born as having food value, they are often gathered by emigrants from the British Isles who cook and serve them in the same manner as asparagus.

Rhizomes of the same species, or its variety *esculentum*, furnish natives of the South Sea Islands, Canary Islands, and other regions with material for bread-making. Warabi starch, described in Volume I, is made from the rhizome.

MACROSCOPIC STRUCTURE.—The deeply buried *rhizome* is long, tough, and black in color. From it arise singly the spreading pinnate *leaves* (fronds), up to about 1 meter wide, borne on long stout *petioles* (stipes), up to 1 cm. or more in diameter, covered with a mat of hairs. The petioles are edible before the leaves unfold.

MICROSCOPIC STRUCTURE. Petiole.—The following description applies to the edible stage. The tissues are (1) *epiderm* of longitudinally elongated, thin-walled cells, often containing purple sap, and numerous exceedingly long (up to several millimeters), thin-walled, jointed hairs; (2) *collenchyma*, several cells thick; (3) *ground parenchyma*, containing chlorophyl grains, through which run (4) detached *fibro-vascular bundles*.

The *bundles*, as in all ferns, are of the concentric type with zylem in the center, surrounded by phloem, the whole enclosed by a starch sheath and, outside of that, an endoderm. The vessels are mostly broad, with bordered pits, less often narrow with spiral thickenings. *Sclerenchyma* *strands*, so marked in mature petioles, are not evident at the edible stage.

Chief Structural Characters.—Petiole fleshy, densely hairy.

Epidermal hairs long, jointed. Fibro-vascular bundles concentric; vessels mostly broad with bordered pits.

CHEMICAL COMPOSITION.—The only available analysis of the shoots is that reported by Chung and Ripperton[1] of the fresh material from the Hawaiian market. An analysis of meal from the dried rhizome by Zlataroff[2] is also included in the table below:

Composition of Brake

	Water	Protein	Fat	N-f. ext.	Starch	Fiber	Ash	Sand
	%	%	%	%	%	%	%	%
C. and R.:								
Shoots.......	91.28	1.02	0.08	5.59	....	1.45	0.58	......
Zlataroff:								
Rhizome meal	8.34	....	....	....	46.00	22.11	10.48	1.52

Mineral Constituents.—Chung and Ripperton[1] found: calcium 0.008, iron 0.0015, and phosphorus 0.017 per cent; also alkalinity of ash 5.5 expressed as cubic centimeters of normal acid per 100 grams of fresh vegetable.

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[1] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[2] Z. Unters. Nahr.-Genussm. 1918, **35**, 483.

LEAVES AND STEMS OF THE GRASS FAMILY

(*Gramineæ*)

The vegetative organs of the grass family in the temperate zone have food value only for cattle, but in the tropics, particularly of the Orient, the undeveloped leaves and stems of members of the bamboo tribe (*Bambuseæ*), known as bamboo shoots, are common vegetables.

BAMBOO SHOOTS

Fr. Bambou. It. Bambú. Ger. Bambus. Jap. Take-noko.
Chin. Choke-sun.

Miyake and Tadokoro[1] state that in the warmer regions of Japan shoots of *Phyllostachys mitis* Riv. and *P. quilioi* Riv. are used, while in the northern regions *Sasa paniculata* Shib. et Mak. is the common species.

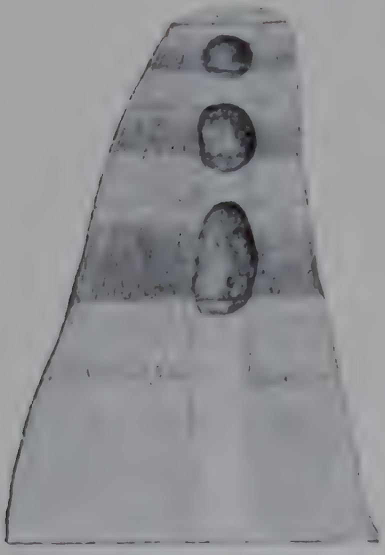

Fig. 44.—Bamboo Shoot. Median longitudinal section showing three dense internodal zones (dark), each with a cavity, translucent nodal zones (light), and numerous vascular bundles. Transverse division in each nodal zone is formed by bundle branches belonging to leaf trace. × ½. (A.L.W.)

Bamboo shoots are canned in Canton, China, and shipped in considerable quantities to the Chinese residents in the United States. The description which follows is based on our examination of canned, decorticated shoots up to 9 cm. long and 8 cm. in diameter at the base.

MACROSCOPIC STRUCTURE (Fig. 44).—The jointed character of the mature *stem* is prefigured by the round or oval cavities separated by partitions. The internodal tissues in the zones surrounding the lower portion of each cavity are more opaque (darker in the figure) than the nodal tissues, which are glassy and transparent. Through both run numerous bundles which, in each node at a place about on a level with the top of the cavity, abruptly branch forming a distinct but irregular transverse division line as seen in longitudinal section. The branches belong to the leaf traces.

MICROSCOPIC STRUCTURE (Figs. 45 and 46). **Ground Tissue** (*p*).—In the internodes the cells are arranged in longitudinal rows without intercellular spaces, and the vascular bundles are without branches; in the nodes the cells are well rounded, intercellular spaces are numerous, and the bundles send out small transverse branches as noted above. Each cell in some preparations contains a small rosette crystal of unknown composition.

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[1] J. Col. Agr. Tohoku Imp. Univ. Japan, 1911, **4**, 251.

Fibro-Vascular Bundles.—Cross (Fig. 45) and longitudinal (Fig. 46) sections show that the structure is of the monocotyledonous type. The *bast fibers* (*f*), being immature, are thin-walled. The *sieve tubes* (*s*), occur in groups and are remarkable for their large size (up to 30 μ). They are accompanied by narrow *companion cells* (*c*). Spiral vessels (*sp*), up to 30 μ, smaller *annular vessels* (*an*), and large *reticulated vessels* (*ret*), up to 160 μ, at this stage with indistinct markings, characterize the xylem. Small elongated *parenchyma cells* (p^1) surround the pitted vessels.

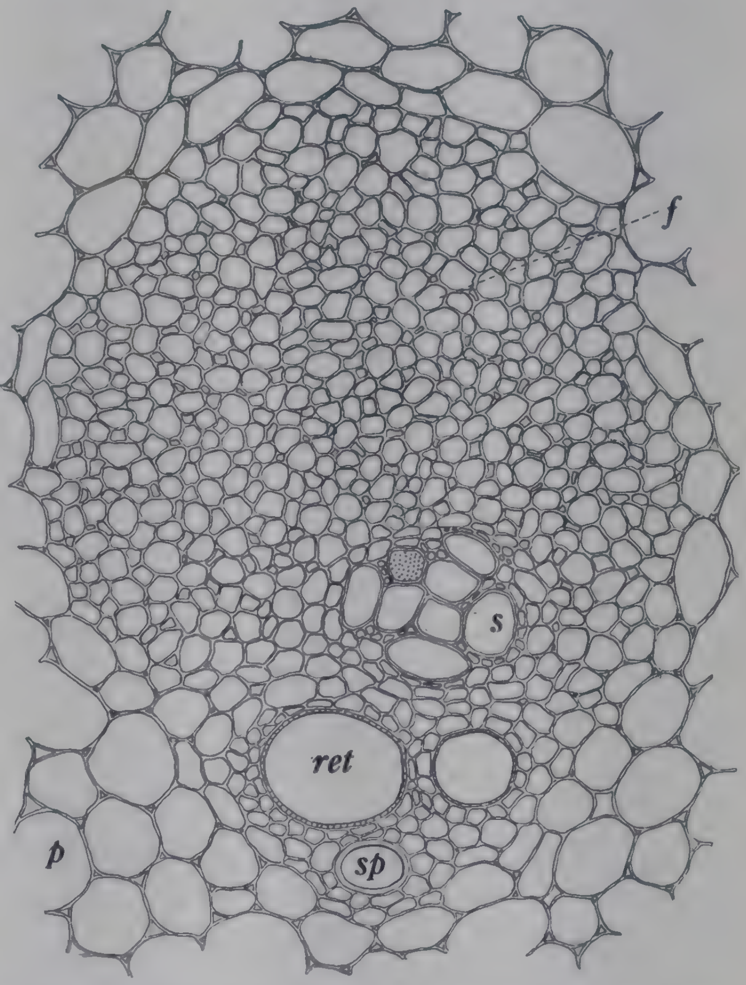

FIG. 45.—Bamboo Shoot. Immature vascular bundle in cross section. *p* parenchyma of ground tissue; *f* mass of fibers; *s* sieve tubes surrounded by companion cells; *ret* faintly reticulated vessels; *sp* spiral vessel. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Shoots jointed, with cavities between the nodes; bundles conspicuous in nodes and internodes, branching to leaf traces in nodes.

Parenchyma cells elongated in internodes, rounded with intercellular spaces in nodes. Bast fibers and reticulated vessels (up to 160 μ) thin-walled, immature.

CHEMICAL COMPOSITION.—Miyake and Tadokoro[1] analyzed the fresh shoots of *Sasa paniculata* and Chung and Ripperton[2] those of *Bambusa* spp. after removal of the outer sheath, with results given in the following table:

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[1] Loc. cit.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

COMPOSITION OF BAMBOO SHOOTS

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sugars, reducing	Sucrose	Pentosans	Fiber	Cellulose	Ash
	%	%	%	%	%	%	%	%	%	%	%
M. and T.:	91.35	2.72	1.94	0.22	3.14	0.53	0.15	1.77	1.44	1.19	1.13
C. and R.:	93.08	1.84	......	0.13	3.17	......	......	......	1.01	.....	0.77

Composition of Parts of the Shoot.—Komatsu and Tanaka,[1] by analysis of shoots from five different sections of the jungle cut into five pieces each, showed that the lowest percentages of total carbohydrates but the highest of simple nitrogenous substances and fatty acids were present in the apical part, while the pentosan content varied little throughout.

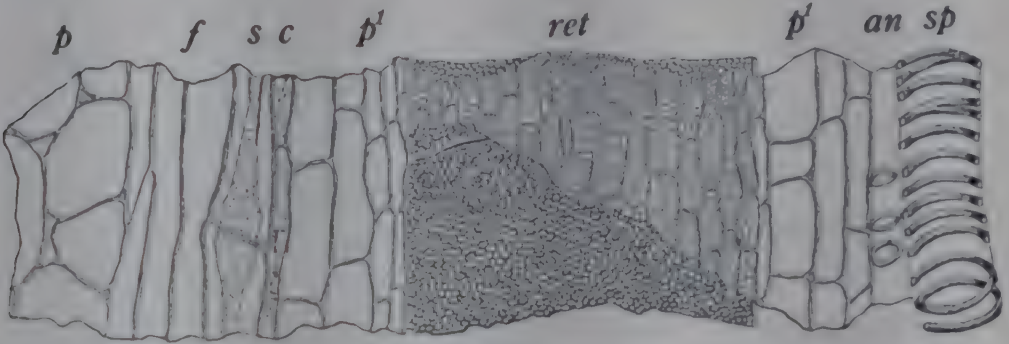

FIG. 46.—Bamboo Shoot. Elements of immature vascular bundle in longitudinal section. *p* parenchyma of ground tissue; *f* fibers; *s* sieve tube; *c* companion cells; *ret* broad reticulated vessel partly covered by p^1 thin-walled parenchyma; *an* annular vessel; *sp* spiral vessel. × 160. (K.B.W.)

Influence of Development on Composition.—Komatsu and Tanaka[1] note a decrease in the percentage of ash with growth. Nagasawa[2] notes in shoots of *Phyllostachys quilioli* a decrease in water, total nitrogen, and ash and an increase in fat, cellulose, and lignin. The maximum for reducing sugars was in January, the minimum in September. Other studies by Tanaka, by Kamiya, by Tashima, and by Nishioka appear in the Anniversary Volume, which is not available.

Non-Protein Nitrogenous Constituents.—Kozai[3] demonstrated in the fresh shoots of *Phyllostachys mitis* the presence of *tyrosine*, and of smaller amounts of *asparagine*, *guanine*, *xanthine*, and *hypoxanthine*;

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[1] Mem. Col. Sci. Kyoto Univ. 1925, **9**A, 1.

[2] Anniv. Vol. Masumi Chikashige 1930, p. 183; Chem. Abs. 1931, **25**, 983.

[3] Bul. Imp. Col. Agr. Dendrol. Tokyo 1890, **1**, 37.

Totani[1] found *adenine*, *choline*, and *betaine*; Miyake[2] isolated from 30 kilos of the fresh shoots of *Sasa paniculata* xanthine 0.095, hypoxanthine 0.060, adenine 0.090, guanine 0.031, tyrosine 1.500, and asparagine 1.000 grams.

Acids.—Sasaoka[3] found *glucuronic*, *oxalic*, *tartaric*, *citric*, and *lactic acids*.

Carbohydrates.—In addition to determination of the reducing sugars, sucrose, pentosans, and cellulose, as given in the table above, Miyake and Tadokoro[4] showed that *xylan* was present in greater amount than *araban*, that galactan, starch, and methylpentosans were absent, and that a trace of *lignin* was present.

Sasaoka[3] isolated dextrose and *l*-xylose, also an unknown sugar yielding an osazone melting at 188° C. in the expressed juice.

Komatsu and Sasaoka[5] expressed 10 liters of juice from 12 kilos of the shoots of *Phyllostachys quilioli* F.M. containing 160 grams (1.60 per cent) of reducing sugars. By precipitation with lead acetate, removal of the lead from the solution, extraction of impurities with ether, and concentration, 43 grams (0.43 per cent) of dextrose were isolated. On removal of the remainder of the dextrose with yeast, 5.4 grams (0.054 per cent) of *l-xylose* were separated.

Mineral Constituents.—Chung and Ripperton[6] found: calcium 0.005, iron 0.0007, and phosphorus 0.044 per cent, also alkalinity of the ash 7.7, expressed as cubic centimers of normal acid per 100 grams fresh vegetable.

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[1] Z. physiol. Chem. 1909, **62**, 113; 1911, **70**, 388.

[2] J. Col. Agr. Tohoku Imp. Univ. 1911, **4**, 261.

[3] Anniv. Vol. Masumi Chikashige 1930, p. 175.

[4] Loc. cit.

[5] Bul. Chem. Soc. Japan 1927, **2**, 57.

[6] Loc. cit.

LEAVES OF THE PALM FAMILY

(*Palmaceæ*)

In addition to a great variety of fibers and various other technical products, trees of this family yield staple foods, among which the date and cocoanut are described in the sections on fruits and nuts. Sago is obtained from the trunk of several species. A single product belonging with leaves is described below.

PALM SHOOTS

Fr. Choux palmistes. It. Cavolo palmista. Ger. Palm Kohl.

Terminal shoots of various species of the palm family, known as palm cabbage, palmetto cabbage, palm hearts, etc., are staple vegetables in the tropics and subtropics. Among the species are *Inodes palmetto* Cook (*Sabal palmetto* Lodd.) of the United States and *Oreodoxa oleracea* Mart. of the West Indies.

Tinned material, labeled "Choux palmistes au naturel," was examined by the authors.

MACROSCOPIC STRUCTURE.—The blanched, tender *shoots* consist of sheathing leaf blades and petioles. They resemble large asparagus shoots.

MICROSCOPIC STRUCTURE.—The elements of both the petiole and leaf blade are similar.

Epiderm.—The cells are small, polygonal, thin-walled, often end to end in rows. Stomata are numerous.

Ground Tissue.—Most of the cells are small, rounded, and thin-walled; some, however, are several times larger and contain *raphides* in bundles.

Fibro-vascular Bundles.—These are of the palm type, but at the edible stage are not fully developed. Numerous thin-walled *fibers* form a sheath with *stegmata* on the surface. There are two groups of *phloem* (see Cocoanut, Volume I). The *sieve tubes* are inconspicuous. *Spiral*, *annular*, and *reticulated vessels* of various sizes and large *pitted vessels* (up to 135 μ) are the most striking vascular elements.

Chief Structural Characters.—Shoots of sheathing leaves and petioles.

Epiderm of small cells and stomata; ground tissue of small parenchyma cells and larger raphides cells; bundles with fiber sheath surrounded by stegmata; phloem groups two; pitted vessels up to 135 μ.

SHOOTS, BULBS, AND LEAVES OF THE LILY FAMILY

(*Liliaceæ*)

This family is represented by (1) asparagus (*Asparagus officinalis* L.) belonging to the tribe *Asparagineæ*, (2) the lily group (*Lilium*), and (3) the onion group (*Allium*); both of the latter groups are classed in the tribe *Lilieæ*.

COMPARATIVE MACROSCOPIC STRUCTURE.—The edible portion of asparagus consists of stem with scales subtending undeveloped branches. Garlic and leek have flat leaves; onions, chives, and shallot, round leaves, the distinction between the two surfaces being lost a short distance above the ligule. The bulb of garlic is divided into " cloves " enclosed within a common scaly sheath. A similar division also takes place in " multiplier onions " and occasionally in common onions. The scape of " top onions " and some varieties of garlic bears bulblets instead of, or together with, flowers. Members of the onion group have scales in concentric circles and during the first year are stemless, that is the stem is represented only by the disk beneath the edible bulb, thus distinguishing the group sharply from the lilies which have scales in fingers and leafy stems.

COMPARATIVE MICROSCOPIC STRUCTURE.—Leaves and stems of all members of the family here considered, in common with many monocotyledonous plants, have longitudinally elongated *epidermal cells* and occasional stomata, the elongation of the cells being especially marked in the tissue of the leaf proper, that is the green blade, of the onion group. A *subepidermal layer* of palisade cells forms a complete circle in the round leaves of the onion and chives, but is represented by isodiametric cells in the bulbs.

Latex tubes are present in the bulbs and leaves of all the members of the onion group. These, according to De Bary,[1] may secrete oil of garlic, the characteristic constituent of the group. *Raphides* occur in asparagus, *monoclinic prisms* in the bulbous part of garlic, onion, and leek. *Starch* is abundant in lily bulbs.

COMPARATIVE CHEMICAL COMPOSITION.—Tanret describes two *sugars* present in asparagus; Tollens found *manitol*. The chief odorous constituents of the onion group are *allyl* and *allyl-propyl disulphides*.

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[1] Comp. Anat. Phan. Ferns, Oxford, 1884, p. 146.

ASPARAGUS

Asparagus officinalis L.

Fr. Asperge. Sp. Espárrago. It. Sparagio. Ger. Spargel.

A native of central and southern Europe and temperate and subtropic regions of western Asia, asparagus was cultivated by the Greeks and Romans before the Christian era. It retains its excellence well on canning.

The plant is diœcious and is remarkable for the absence of green leaves, the green needle-like branches (*cladodes*) in the axils of the scale-like true leaves serving in place of leaves as photosynthetic organs. It is said that at one time the berries were used as a coffee substitute.

Shoots of other plants in the temperate zone, some wild, others cultivated, are used locally for food. Among these are brake (*Pteris aquilina* L.), various milkweeds (*Asclepias* spp.), poke weed (*Phytolacca americana* L.), and hop (*Humulus Lupulus* L.). Hop shoots, known as hop-asparagus, are eaten in Germany.

MACROSCOPIC STRUCTURE.—The fleshy *shoot*, as cut for food, consists of a *stem* with spirally arranged scales about one-half inch long, each scale bearing in its axis an incipient primary branch with minute scales in which are rudimentary secondary branches. The cladodes are borne on the tip of the main stem, but are found in greater numbers on the primary and secondary branches in the axils of minute scales. Only the lower part of the main stem with its scales has reached full development at the cutting stage. The color varies from white to dark green. Certain French varieties are designated as violet. At the base all varieties are more or less blanched.

MICROSCOPIC STRUCTURE.—Only the stem and scales have well-developed tissues, the branches and cladodes being in the formative stage.

Stem (Figs. 47 and 48).—Four distinct zones are present in the young and tender shoot a short distance below the tip: (1) *epiderm* (*ep*, ep^2) of straight-walled cells, about twice as long as broad, with somewhat thickened cuticularized outer walls, and sunken stomata (*sto*); (2) *primary cortex* (*pc*) of longitudinally elongated cells, several thick, with intercellular spaces, containing chlorophyl grains or here and there a bundle of raphides (*r*); (3) *pericycle* (*per*) of small characterless cells with very few if any intercellular spaces; and (4) *central cylinder* (stele) of rounded, thin-walled parenchyma cells (*p*), with intercellular spaces, among which are scattered typical closed fibro-vascular bundles (fv^1, fv^2).

On further growth, when the shoot is tough and inedible, the walls of the *epiderm* become finely beaded. The well-rounded cells of the *primary cortex* as seen in cross section of the tender shoot have walls thicker than those of the pericycle, but with further growth the reverse soon becomes true and the cells of the pericycle become longitudinally elongated and sclerenchymatized. All the cells of the cortex, except those with raphides, contain small chlorophyl grains.

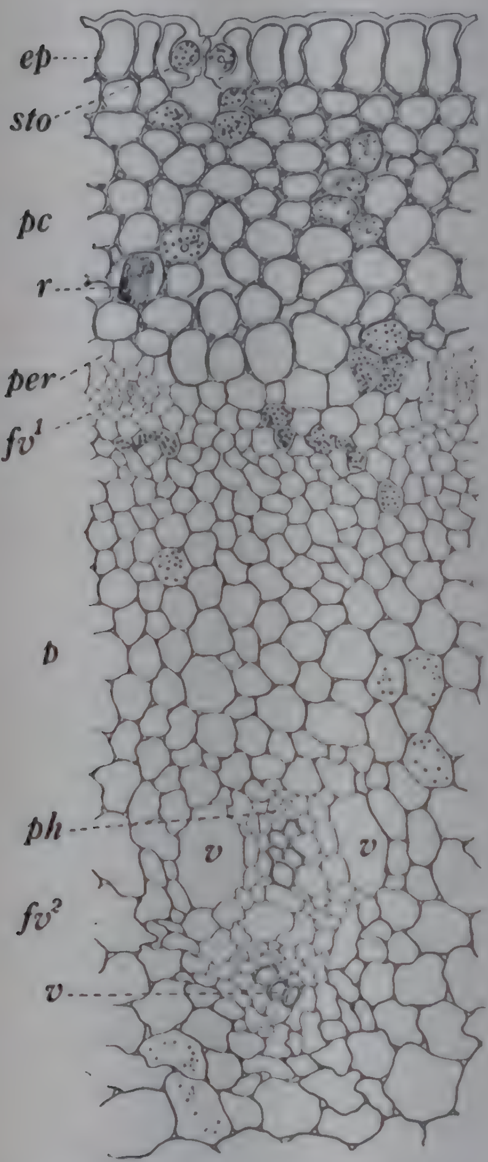

FIG. 47.—Asparagus. Young stem in cross section. *ep* epiderm with *sto* sunken stoma; *pc* primary cortex with chlorophyl grains and *r* raphides; *per* pericycle; fv^1 incipient vascular bundle; *p* parenchyma of stele; fv^2 large vascular bundle with *ph* phloem and *v* vessels. ×160. (K.B.W.)

Adjoining the pericycle in the stele in Fig. 47 is shown a *fibro-vascular bundle* (fv^1) in the formative stage with thin-walled characterless elements. A more fully developed but still immature bundle (fv^2) occurs further inward, with vessels (*v*) at the angles of a triangle, the three at the lower angle being spiral or annular with thickened walls, the other two being reticulated, large, but with very thin walls at this stage.

Scales (Fig. 48).—The epiderms of large mature scales are of longitudinally elongated cells, with beaded, very slightly wavy walls. Sunken stomata are scattered over the *lower* (outer) *epiderm* (*aep*) but in the *upper epiderm* (*iep*) are few in number and found only near the tip.

A *mesophyl* of loosely arranged, rounded, thin-walled cells containing a moderate number of chlorophyl grains forms the bulk of the scales. Bundles of *raphides* (*r*), like those of the stem, occur here and there in cells which are somewhat more rounded and occasionally larger than those of the surrounding tissue. The *fibro-vascular bundles* (*fv*) contain the same elements as those of the stem.

These scales, although morphologically leaves, do not have a palisade layer and are not abundantly supplied with chlorophyl grains, whereas the cladodes which develop later, although morphologically branches, have a well-developed *palisade layer* and are rich in chlorophyl grains.

The small scales, folded longitudinally one within another, enclosed within the big scales and clustered over the growing tip, have only elementary tissues. The small, thin-walled cells of both epidermal layers are narrow, elongated, becoming isodiametric at the apex of the scale (Fig. 48, *ep*¹). Sunken stomata occur away from the edges. The mesophyl cells with bundle traces are characterless.

Chief Structural Characters.—Stem fleshy with immature scales, branches, and cladodes.

Epiderm of stem and scales of elongated cells and sunken stomata; primary cortex, central cylinder of stem, and mesophyl of scales and cladodes containing chlorophyl grains and raphides; bundles immature, of monocotyledonous type.

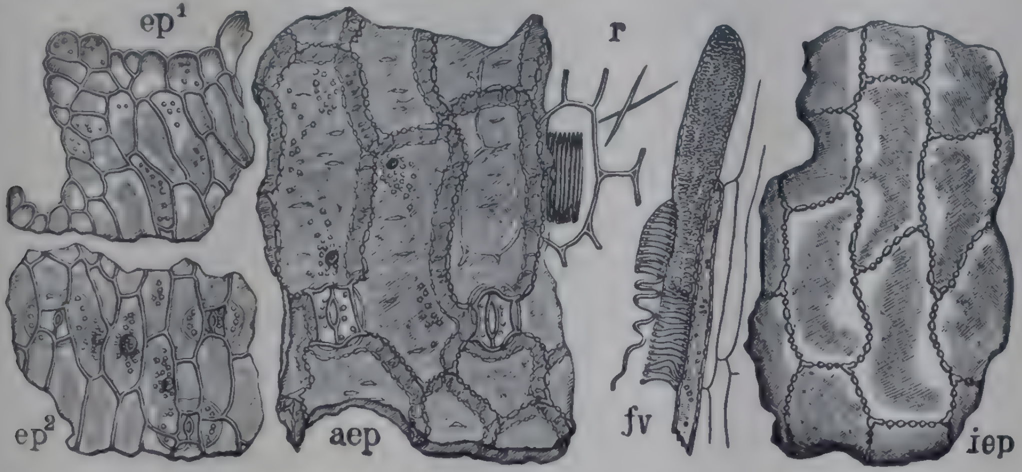

Fig. 48.—Asparagus. Elements of shoot in surface view. *ep*² epiderm of stem 7 cm. from tip. *ep*¹ outer epiderm of immature scale at edge. Mature scale: *aep* lower epiderm; *fv* fibro-vascular bundle; *r* raphides in mesophyl cell; *iep* inner epiderm. × 160. (K.B.W.)

CHEMICAL COMPOSITION.—Analyses made by Richardson[1] of one sample of large white asparagus and two of small green illustrate well the proximate composition of the vegetable. An analysis by v. Schleinitz[2] is also included below:

Composition of Asparagus

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Richardson:							
Large white	93.61	2.64	....	0.23	1.90	0.65	0.97
Small green	94.25	1.77	....	0.25	2.42	0.78	0.53
" "	94.02	2.07	....	0.27	2.33	0.79	0.52
Aver.	**93.96**	**1.83**	....	**0.25**	**2.55**	**0.74**	**0.67**
v. Schleinitz	95.34	1.64	1.00	0.11	1.74	0.63	0.54

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[1] U. S. Dept. Agr. Rep. 1883, 234, 235.

[2] Landw. Jahrb. 1918, **52**, 131.

Influence of Fertilizers on Composition.—Determinations made at the Münster Station[1] of the usual proximate constituents in 21 samples grown with different fertilizers did not bring out sufficient difference in composition of the dry matter to warrant positive conclusions.

Proteins.—The analyses made at both the Münster Station and the U. S. Department of Agriculture show that only about half of the total protein consists of true protein.

Amides.—*Asparagine*, although so named because of its occurrence in asparagus shoots, is by no means limited to this plant.

Fatty Oil of Seed.—The seed contained, according to determinations by " N. and H.,"[2] 11.7 per cent of fat with the following values: refractive index at 25° 1.4746 (1.4753), saponification number 193.4 (194.1), iodine number 140 (137.1), acid number 6.5, and unsaponifiable matter 0.96 per cent. The figures in parentheses are quoted from other authors.

Carbohydrates.—Tanret[3] describes two sugars, *asparagose* and *pseudo-asparagose*, which he isolated from the roots and green fruits but was unable to find in the ripe fruits or the shoots.

Wichers and Tollens,[4] who have studied the distribution of carbohydrates in the root system and shoots at different seasons, found hexoses in the juice of the shoots but no polysaccharides. They were unable to prove that *mannite* (mannitol), $C_6H_{14}O_6$, was present, but later Tollens[5] found that after allowing the juice to stand for some time the crystalline substance separated as small needle-shaped crystals, melting at 167 to 168° C. These were optically active in a borax solution but not in an aqueous solution. Busolt[6] corroborated Tollen's findings. Apparently organisms or enzymes are instrumental in the formation of mannite.

In the 21 samples of asparagus shoots analyzed at the Münster Station[7] the *pentosans* ranged from 8.04 to 14.94 per cent, calculated to the dry matter.

Mineral Constituents.—The average percentages of water, ash, and ash constituents in 4 samples of asparagus shoots, cut May 15, analyzed at the Massacusetts Station, as compiled by Haskins,[8] follow:

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[1] König: Chem. mensch. Nahr.-Genusm., Berlin, 1903, **1**, 786.

[2] Z. angew. Chem. 1916, **29**, I, 337.

[3] Compt. rend. 1909, **149**, 48.

[4] J. Landw. 1910, **58**, 101, 113.

[5] Ibid. 1911, **59**, 429.

[6] Ibid. 1912, **60**, 393.

[7] Loc. cit.

[8] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

Water	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3
%	%	%	%	%	%	%	%
93.0	0.72	0.28	0.02	0.06	0.02	0.04	0.04

Minor Mineral Constituents. *Iron.*—Shoot 12 mg. per kilo, fresh basis (Häusermann, quoted by Sherman).[1] Shoot, 16 samples, 125 to 340, aver. **207** mg. per kilo, dry basis (Remington and Shiver).[2] Shoot 7.9 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Aluminum.—Shoot 120 mg. per kilo, dry basis (Bertrand and Lévy).[4]

Manganese.—Shoot, 8 samples, 27.7 to 86.0, aver. **42.1** mg. per kilo, dry basis (Remington and Shiver).[2]

Copper.—Shoot, 9 samples, 11.6 to 24.0, aver. **15.3** mg. per kilo, dry basis (Remington and Shiver).[2] Shoot 7.0 mg. per kilo, fresh basis (Guérithault).[5] Shoot 1.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Shoot 3.2 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

Arsenic.—Shoot 0.1 mg. per kilo, fresh basis (Jadin and Astruc).[8]

CHINESE LILY

Lilium Brownii Poit.

Bulbs of several species of lilies are used as food in China and Japan. Blasdale[9] reports that the bulbs of only one species (*L. japonicum* var. *Brownii*) were found on sale in the Chinese Quarter of San Francisco. He further states that this is the species ordinarily known as *L. Brownii* Poit.

Other species named as food plants in the Far East by Penhallow,[10] Bretschneider,[11] and Davy[12] are *L. glehni*, *L. tigrinum*, *L. concolor pulchellum*, *L. cordifolium*, *L. auratum*, and *L. elegans*. According to Blasdale,[9] the Indians of Nevada and California use for food bulbs of *L. parvum* Kellogg and *L. pardalium* Kellogg.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.
[2] J. Ass. Off. Agr. Chem. 1920, **13**, 129.
[3] J. Biol. Chem. 1928, **78**, 215.
[4] Bul. soc. hyg. aliment. 1931, **19**, 359.
[5] Ibid. 1927, **15**, 386.
[6] J. Biol. Chem. 1929, **82**, 465.
[7] Bul. soc. hyg. aliment. 1928, **16**, 457.
[8] Compt. rend. 1912, **155**, 291.
[9] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.
[10] Am. Nat. 1882, **16**, 119.
[11] Useful Plants of Japan, Tokyo, 1895.
[12] Erythea, 1898, **6**, 26.

MACROSCOPIC STRUCTURE.—The *bulb* differs from those of species of *Allium* in that the scales are all narrow, finger-like, arranged about a central bud, and not forming concentric rings as seen in cross section; furthermore they are deeply buried in the ground.

MICROSCOPIC STRUCTURE. Scale.—The *lower* (*outer*) *epiderm* consists of wavy-walled more or less elongated cells and numerous stomata. Characteristic of the *mesophyl* are the starch grains up to 100 μ (Fig. 49). These are either isodiametric or elongated with excentricity up to 1 : 6. Among the forms are elliptical, pear-shaped, spindle-shaped, sickle-shaped, and irregular. The hilum is indistinct and located in the broad end. Aggregates of two or three grains occur rarely. Polarization crosses are very distinct. The *upper epiderm* consists entirely of elongated cells, the walls of which are strongly wavy with swellings at each turn.

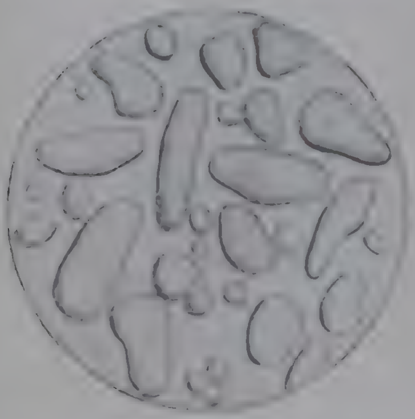
FIG. 49.—Chinese Lily. Starch from bulb. × 160. (A.L.W.)

CHIEF STRUCTURAL CHARACTERS.—Bulb of finger-like scales.

Epidermal cells with wavy walls; mesophyl containing starch grains, up to 100 μ, with excentric hilum.

CHEMICAL COMPOSITION.—Blasdale[1] gives analyses of the fresh and dried bulbs of *L. japonicum Brownii* from the Chinese market of San Francisco.

COMPOSITION OF CHINESE LILY BULBS (BLASDALE)

	Water	Protein	Protein, pure	Fat	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Fresh..	66.72	2.33	1.55	0.59	0.00	4.16	17.74	0.75	1.24
Dried..	10.16	5.57	5.00	0.37	0.00	2.84	62.65	1.64	2.68

CHIVES

Allium Schœnoprasum L.

Fr. Civette. Sp. Cebollino. It. Cibollina. Ger. Schnittlauch.

Chives—the plural form is more commonly used than the singular—grow wild throughout Europe and, according to Gray, in North America from New Brunswick and the Great Lakes to the Pacific and northward.

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[1] Loc. cit.

hey are cultivated for the leaves which are used for flavoring soups, auces, and various dishes. The plant is perennial and grows in masses.

MACROSCOPIC STRUCTURE.—The *leaves* are narrow-cylindrical nd hollow, arising from small bulbs. Heads of purplish flowers are orne at the end of leaf-like scapes. In general morphology the plant iffers from the onion only in size.

MICROSCOPIC STRUCTURE. Bulb.—This is similar in structure o the onion, but crystals are absent or inconspicuous. The tissues on oth sides are practically the same, the subepidermal layers being of sodiametric cells and chlorophyl grains being lacking throughout.

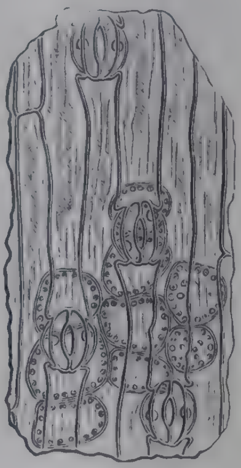

FIG. 50.—Chives. Leaf in surface view. Lower epiderm with stomata showing palisade cells with chlorophyl grains beneath. × 160. (K.B.W.)

Leaf (Fig. 50).—The bifacial characters are lost beginning at the region of the ligule. Except at the apex, where the cells are but little elongated nd stomata are absent, the cells of the *epiderm* are narrow, thin-walled, and greatly elongated. They re arranged end to end in longitudinal rows. The walls are usually straight except where they bend to join the stomata. They are delicately striate and covered with a bloom. A ridge, evident in cross section, follows along the center of each cell. Longitudinal bands of tissue consist entirely of the epidermal cells without stomata. Alternating with these are bands containing numerous stomata, one usually occurring at the end of each epidermal cell.

Palisade cells constitute the *subepiderm* with typical arrangement of chlorophyl grains lining the walls. Hartwich[1] considers that the elongated, thick-walled elements present in the region where subepiderm passes into mesophyl are fibers, but their analogy to the *latex tubes* of related species is evident on careful examination. A loose tissue ruptured at the hollow center forms the *mesophyl*. Small spiral vessels predominate in the fibro-vascular bundles.

CHIEF STRUCTURAL CHARACTERS.—Leaf narrow, hollow.

Epiderm of elongated cells and stomata in bands; subepiderm of palisade cells with chlorophyl grains. Latex tubes thick-walled.

CHEMICAL COMPOSITION.—Dahlen[2] and Chung and Ripperton[3] report the following analyses of the leaves:

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[1] Beythien, Hartwich, Klimmer: Handb. Nahrungsm.-Unters., Leipzig, 1915, **2**, 220.

[2] Landw. Jahrb. 1875, **4**, 613.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

Composition of Chives

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Dahlen	80.83	5.14	0.78	8.46	2.39	2.40
C. and R.	91.22	2.60	0.33	3.09	1.48	1.28

Mineral Constituents.—Dahlen[1] found 0.258 per cent of phosphoric acid.

Chung and Ripperton[2] found: calcium 0.048, iron 0.0084, and phosphorus 0.057 per cent; also alkalinity of ash 12.6 expressed as cubic centimeters of normal acid per 100 grams of fresh vegetable.

ONION

Allium Cepa L.

Fr. Ognon. Sp. Cebolla. It. Cipolla. Ger. Zwiebel.

Apparently a native of western Asia, the common onion was cultivated in ancient Egypt, India, and Greece, and at an early date in China.

Onions are generally grown from seed and do not produce flowers the first year. When the tops, which are characterized by their round, hollow leaves, die down, the bulbs are lifted and stored for winter use. Sowed thickly, small onions, known as "sets," are obtained which, planted the next season, may be gathered early and eaten with part of the tops either raw or cooked as "Spring onions" or allowed to form mature bottoms.

Two varieties have been developed, differing markedly from the type in the method of propagation. One of these, known as top, Egyptian, or perennial onion (var. *bulbellifera* Bailey), bears bulblets on the scape, instead of, or in addition to, flowers, which, left to themselves, take root when the top falls over, or may be separated and planted. The second variety, known as multiplier onions (var. *multiplicans* Bailey), similarly to garlic shows a marked tendency to divide within the outer scales into secondary bulbs which may be separated for planting. The common onion also may divide in the center and even subdivide, producing two or four sets of shoots on sprouting.

The Welch onion (*A. fistulosum* L.), a native of Siberia, does not produce distinct bulbs, but the blanched lower portion of the leaves

[1] Loc. cit.

[2] Loc. cit.

elow the ground is somewhat swollen, tapering gradually to the green op. It is used as a Spring onion.

Shallot (*A. ascalonicum* L.), according to De Candolle, is a variety f the common onion. It produces small pointed bulbs which separate imilarly to garlic into cloves. Bailey gives Syria as its original home.

MACROSCOPIC STRUCTURE.—In form the *bulb* ranges from flat-ened through globular to spindle-shaped. All the *scales* (leaf bases) orm complete layers, appearing as concentric rings in cross section. The outer scales are dry and papery, consequently inedible; the inner scales thick and fleshy. There are white, yellow, and red varieties, the color being chiefly in the dry scales and outer fleshy scales.

Longitudinal nerves, formed by the fibro-vascular bundles, running from base to top like meridians on a globe, are conspicuous to the naked eye, especially on the dry scales. Under a lens the epidermal cells, arranged end to end in longitudinal rows, are evident owing to the collapse of the outer walls. Latex tubes may also be seen as delicate longitudinal lines between the veins.

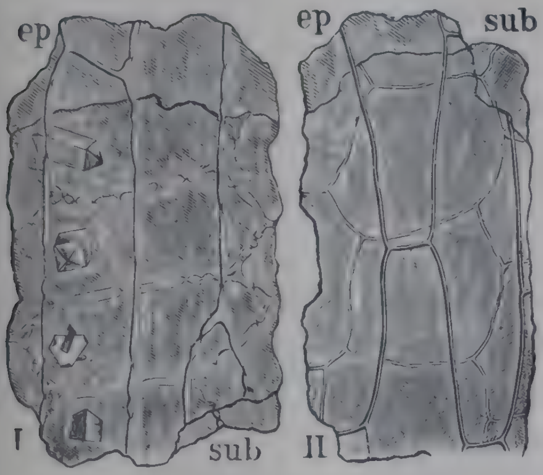

FIG. 51.

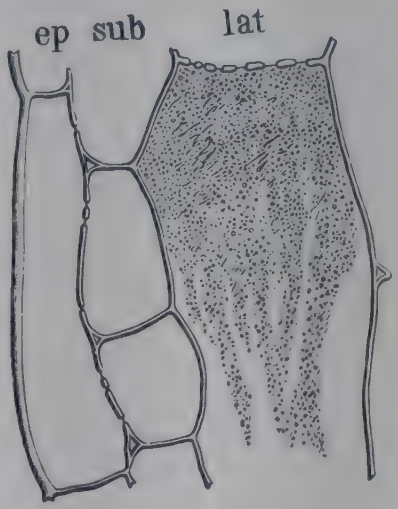

FIG. 52.

FIG. 51.—Onion. I dry scale and II fleshy scale in surface view. *ep* outer epiderm; *sub* subepiderm. × 160. (K.B.W.)

FIG. 52.—Onion. Fleshy scale in longitudinal section. *ep* outer epiderm; *sub* subepiderm; *lat* latex tube with streaming latex. × 160. (K.B.W.)

The leaf loses its bifacial characters near the ligule, becoming practically cylindrical.

MICROSCOPIC STRUCTURE. Scale.—Throughout the bulb, the cells of the *lower* (*outer*) *epiderm* (Figs. 51 and 52, *ep*) are much elongated and arranged end to end in longitudinal rows. They diminish in size toward the apex. On the dry scales the walls are more or less thickened and beaded (Fig. 51, I, *ep*). Sunken stomata occur sparingly, most frequently toward the tip.

Subepiderm (Figs. 51 and 52, *sub*).—The cells are in longitudinal rows, as in the epiderm, but are polygonal-isodiametric or even transversely elongated in mature onions, whereas they are longitudinally elongated in Spring onions. In the dry scales, the walls are somewhat thickened and distinctly beaded, elsewhere thin and indistinctly beaded. Beautiful single, prismatic crystals of calcium oxalate, reaching 50 μ in length, occur in the subepidermal cells of the dry scales. They are seldom found in the fleshy scales of mature onions, although small ones are present in the outer fleshy scales of Spring onions.

In cross section, both the epidermal and subepidermal cells of the bulb are isodiametric. The subepiderm of the leaf is of palisade cells with chlorophyl grains.

Latex Tubes (Fig. 52, *lat*), containing granular contents, occur at intervals between the subepiderm and the mesophyl. Strictly speaking, they are not tubes but large sacs arranged end to end. The dividing walls, or septæ, are distinctly porous.

Mesophyl.—The cells of the ground tissue are thin-walled throughout. Fibro-vascular bundles occur in the inner part. The vessels are largely spiral with variable bands. Annular and reticulated vessels also are present.

Upper (Inner) Epiderm.—As in the outer epiderm, the cells are thin-walled and longitudinally elongated, but are somewhat larger and more variable in size. Sometimes the walls are faintly beaded. Stomata occur sparingly toward the tip.

Chief Structural Characters.—Bulbs flattened, globular, or spindle-shaped, well rounded; in common onion usually with simple core, in multiplier onion with compound core. Color white, yellow, or red.

Epidermal cells elongated in longitudinal rows, walls thickened and porous in dry scales, stomata few; subepiderm of isodiametric or transversely elongated cells, each in the outer scales containing prismatic oxalate crystals; latex tubes forming longitudinal lines evident under a lens; fibro-vascular bundles with spiral and reticulated vessels.

CHEMICAL COMPOSITION.—The composition of onions at three different stages of development, also of red, yellow, and white varieties and top onions, is shown by analyses made at the U. S. Department of Agriculture[1] and at the New York Agricultural Experiment Station.[2] Analyses by v. Schleinitz[3] show the composition of the bulbs and tops, and by Agcaoili[4] of young onions.

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[1] Rep. 1881–82, p. 555; 1883, p. 240.

[2] Rep. 1883, p. 151.

[3] Landw. Jahrb. 1918, **52**, 151.

[4] Philippine J. Sci. 1916, **11**, 91.

COMPOSITION OF ONIONS

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
U. S. Dept. Agr.:						
Giant Della Rocca						
June 29	91.05	1.12	0.60	5.06	1.22	0.95
July 10	87.19	1.57	0.82	7.87	1.35	1.20
July 20	93.52	1.10	0.36	3.77	0.63	0.62
White	85.26	2.28	0.22	10.80	0.76	0.68
N. Y. State Agr. Exp. Sta.:						
Red Wethersfield	90.32	1.04	0.24	7.39	0.59	0.42
Yellow Danvers	88.20	1.14	0.24	9.23	0.71	0.48
Top onions	81.53	2.11	0.24	14.69	0.74	0.69
V. Schleinitz:						
Bulbs	89.16	1.10*	0.12	8.44	0.71	0.48
Edible Leaves	92.45	1.34†	0.29	3.95	0.94	1.03
Agcaoili	89.14	1.27	0.34	6.71	1.80	0.74

* Pure protein 0.64%. † Pure protein 1.11%.

Analyses by Kihara[1] of the edible bulbs of *A. bakeri*, *A. ledefourianum*, and *A. fistulosum* L. var. *cæspitosum* Makino show respectively: water 70.43, 60.0, and 75.87 per cent, and on the dry basis protein 10.31, 6.83, and 10.99, fat 0.40, 0.50, and 1.61, soluble carbohydrates 61.00, 64.40, and 51.42, pentose 2.20, 1.55, and 5.30, fiber 2.45, 1.87, and 7.12, and ash 2.20, 1.88, and 3.75 per cent. The water extract of all three, after purification with basic lead acetate, yielded with barium hydroxide a precipitate from which was isolated *fructane* (rotation at 18° C. −41.3°) with the same properties as scorodose from *A. Scorodoprasum* L. No starch, dextrin, or inulin was found.

Volatile Oil.—Semmler[2] has shown that the chief constituent of volatile onion oil is allyl-propyl disulphide $(C_3H_5)S \cdot S(C_3H_7)$. A higher sulphide and other substances, yet to be investigated, are also stated to be present.

Carbohydrates.—Meager data are available on the sugars. Dahlen[3] reports 5.78 per cent of *sugar* in yellow and 2.26 per cent in red onions. Wittmann[4] found 0.28 per cent of *pentosans*. *Inulin* occurs in garlic and probably in onion. *Mannite* is said to be present.

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[1] J. Agr. Chem. Soc. Japan 1934, **10**, 417.

[2] Arch. Pharm. 1892, **230**, 434.

[3] Landw. Jahrb. 1875, **4**, 613.

[4] Z. landw. Oesterr. 1901, **4**, 131.

The bulb of the closely allied species *A. scorodoprasum* L. contains, according to Kihara,[1] *scorodose.*

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[2] found 4.70 per cent, dry basis.

Mineral Constituents.—Analyses from the compilations of Wolff[3] and Haskins[4] in terms of percentages of the fresh material follow:

	Water	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Wolff....	86.0	0.74	0.25	0.02	0.16	0.03	0.13	0.04	0.07	0.02
Haskins..	89.2	0.49	0.18	0.01	0.04	0.02	0.07	......	......	......

Minor Mineral Constituents. *Iron.*—Bulb, 6 samples 75 to 265, aver. **156** mg. per kilo, dry basis (Remington and Shiver).[5] Bulb 3 mg. per kilo, fresh basis (Peterson and Elvehjem).[6] Bulb, 2 samples, 4.3, 4.5 mg. per kilo, fresh basis (Toscani and Reznikoff).[7]

Aluminum.—Bulb 93 mg. per kilo, dry basis (Bertrand and Lévy).[8] Bulb 43.1 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[9]

Manganese.—Bulb 3.92 mg. per kilo, dry basis (Quartaroli).[10] Bulb, 5 samples, 47.7 to 96.2, aver. **63.3** mg. per kilo, dry basis (Remington and Shiver).[5]

Copper.—Bulb 23.2 mg. per kilo, dry basis, equivalent to 2.9, fresh basis (Guérithault).[11] Bulb 3.44 mg. per kilo, dry basis (Quartaroli).[10] Bulb, 9 samples, 5.0 to 23.8, aver. **11.5** mg. per kilo, dry basis (Remington and Shiver).[5] Bulb 0.8 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[12]

Zinc.—Bulb 13.8 mg. per kilo, fresh basis (Bertrand and Benzon).[13]

Arsenic.—Bulb 0.03 mg. per kilo, fresh basis (Jadin and Astruc).[14]

GARLIC

Allium sativum L.

Fr. Ail ordinaire. Sp. Ajo. It. Aglio. Ger. Knoblauch.

A native of temperate western Asia, garlic has been cultivated in Egypt and other Mediterranean countries since prehistoric times. It is today highly esteemed in southern Europe although more as a condiment than a food. Garlic bulbs, held together by braiding the dry tops to form strings, are familiar sights in Italian markets. The crop is grown by separating the bulbs into cloves and planting like onion sets. The leaves are flat. In certain varieties, bulblets are produced among the flowers on the scape as in top onions.

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[1] J. Agr. Chem. Soc. Japan 1931, **7**, 1067.

[2] Philippine Agr. 1932, **21**, 53.

[3] Aschenanalysen.

[4] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[5] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[6] J. Biol. Chem. 1928, **78**, 215.

[7] J. Nutrition 1934, **7**, 79.

[8] Compt. rend. 1931, **192**, 525.

[9] Am. J. Physiol. 1929, **90**, 72.

[10] Ann. chim. appl. 1928, **18**, 47.

[11] Compt. rend. 1920, **171**, 196.

[12] J. Biol. Chem. 1929, **82**, 465.

[13] Bul. soc. hyg. aliment. 1928, **16**, 457.

[14] Compt. rend. 1912, **155**, 291.

Rocambole (*A. Schorodoprasum* L.) resembles garlic. It is grown chiefly in Europe where it appears also to grow wild.

MACROSCOPIC STRUCTURE.—The *bulb* is compound, being made up of several, easily separable, sickle-shaped, angular bulbs (" cloves "), the base of a central scape, and thin, transparent, glistening scales of the primary bulb encircling the whole.

Three kinds of scales are present: (1) *papery* (*bulb*) *scales*, similar to the outer dry scales of the onion, several of which surround the whole bulb and one encloses each group of cloves formed from the primary bulb by splitting; (2) *leathery* (*clove*) *scales*, somewhat thicker than the papery scales, often of a pinkish color, each forming a coat for an individual clove; and (3) *fleshy* (*clove*) *scales*, one to each clove, enclosing the bud.

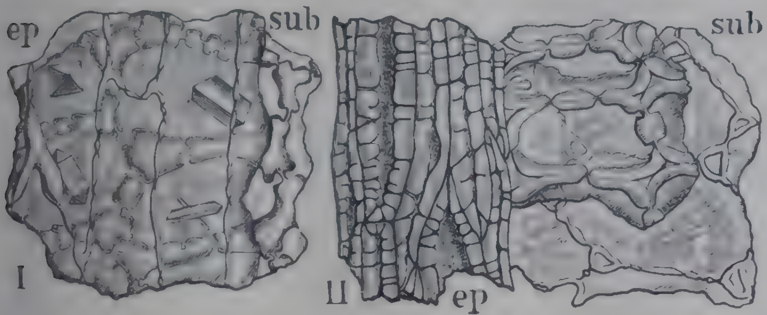

FIG. 53.

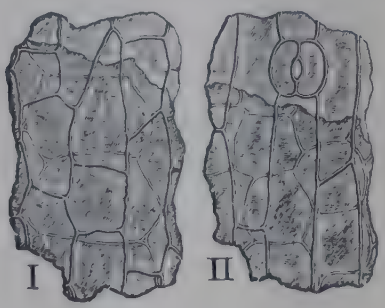

FIG. 54.

FIG. 53.—Garlic. Dry scales in surface view. I papery scale surrounding whole bulb; II leathery scale of clove. *ep* lower epiderm; *sub* epiderm. ×160. (K.B.W.)

FIG. 54.—Garlic. Fleshy (edible) parts in surface view showing lower epiderm and subepiderm. I fleshy scale of clove; II leaf from central bud of clove. × 160. (K.B.W.)

Often only one clove in a group develops, in which case this clove has both papery and leathery scales. Only the fleshy clove scales are valuable. The *bud* consists of a group of leaves, concentric at the base as in a young onion plant, the free ends often being of a marked green color.

MICROSCOPIC STRUCTURE.—The histology differs from that of the onion chiefly in that the cells of the dry scales have more strongly thickened walls.

Papery (**Bulb**) **Scale** (Fig. 53, I).—The cells of the *lower* (*outer*) *epiderm* (*ep*), in addition to being longitudinally elongated as in the onion, are also beaded. The *subepiderm* (*sub*) is more strongly developed than the epiderm, the walls being much thickened and beaded. The cells are often transversely elongated, and each contains a well-developed crystal, often 30 μ long, or less frequently a cluster of a few smaller individuals. *Latex tubes* form distinct nerves, often of a reddish color. The *mesophyl* and *upper* (*inner*) *epiderm* are as in the onion.

Leathery (Clove) Scale (Fig. 53, II).—In the *lower* (*outer*) *epiderm* (*ep*) the cell walls are so strongly thickened and distinctly porous as to convert the cells into sclerenchyma fibers with lumen often narrower than the double walls. Several layers of isodiametric or transversely elongated cells form the *subepiderm* (*sub*). The walls are thickened, especially in the outer layer. An intercellular space is conspicuous at each angle. The *latex tubes* are well developed. The *mesophyl* and *upper* (*inner*) *epiderm* are the same as in the papery scales, except that the mesophyl often has reddish contents.

Fleshy (Clove) Scale (Fig. 54, I).—All the elements are thin-walled and not noticeably different from those of the onion, except that the cells of the lower (outer) epiderm are less strongly elongated.

Bud (Fig. 54, II).—The tissues are delicate. Chlorophyl grains and stomata are noticeable.

CHIEF STRUCTURAL CHARACTERS.—Bulb irregular owing to angular sickle-shaped cloves about central scape, the whole enclosed in papery scales. Groups of cloves with a common paper scale. Each clove with one leathery scale and one fleshy, edible scale about bud.

Papery and leathery scales with more or less strongly thickened, beaded lower (outer) epiderm and subepiderm. Crystals in subepiderm of papery scales. Structure otherwise as in onion.

CHEMICAL COMPOSITION.—Analyses by Dahlen,[1] of the edible part and skin, and by Agcaoili[2] follow:

	Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
	%	%	%	%	%	%	%
Dahlen:							
Edible part...	64.66	6.76	0.06	26.31	trace	0.77	1.44
Outer skin....	0.00	3.30	0.50	46.17	....	46.53	3.50
Agcaoili........	88.01	2.20	0.32	7.27	....	1.17	1.03

Volatile Oil.—According to Semmler,[3] *allyl disulphide*, $(C_3H_5)_2S_2$, not allyl sulphide, $(C_3H_5)_2S$, as believed by earlier investigators, is the chief constituent of volatile garlic oil, present to the extent of about 60 per cent. Allyl-propyl disulphide, $(C_3H_5)S \cdot S(C_3H_7)$, and a third sulphide, $(C_3H_5)S \cdot S \cdot S(C_3H_5)$, were also isolated, the last named forming about 20 per cent of the oil.

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[1] Landw. Jahrb. 1875, **4**, 613.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] Arch. Pharm. 1892, **230**, 434.

Carbohydrates.—Wittmann[1] found 0.93 per cent of *pentosans.*

Chevastelon[2] describes a form of *inulin* $(C_6H_{10}O_5)$ which he isolated as an amorphous powder with a rotation of −39°. It does not reduce copper but is completely hydrolyzed by acid to levulose. It is not fermented by hydrolytic or non-hydrolytic yeasts nor is it hydrolyzed by amylose, but it is acted on by an enzyme, inulase, secreted by *Aspergillus niger* with the formation of fructose.

According to Braecke[3] a sulphur-containing glucoside is present in the parenchyma yielding fructose and volatile oil when acted on by the enzymes occurring in the protein cells of the phloem and bundle sheath. *Starch* occurs in the bundle sheath and the roots.

Enzymes.—See Carbohydrates.

Mineral Constituents.—Dahlen[4] found in the sample of edible part phosphoric acid 0.452 and organic sulphur 0.166 per cent.

Minor Mineral Constituents. *Aluminum.*—Bulb 36 mg. per kilo, dry basis (Bertrand and Lévy).[5]

Manganese.—Bulb 17.84 mg. per kilo, dry basis (Quartaroli).[6]

Copper.—Bulb 10.23 mg. per kilo, dry basis (Quartaroli).[6]

Zinc.—Bulb 10 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

LEEK

Allium Porrum L.

Fr. Poireau. Sp. Peurro. It. Porro. Ger. Lauch.

In the Mediterranean region, where it appears to be native, the leek is grown from seed (not from sets) as a substitute for Spring onions. Elsewhere it is less common.

MACROSCOPIC STRUCTURE.—The blanched bases of the leaves, which form the edible portion, are somewhat swollen but do not form a pronounced bulb. As is true of garlic, the leaf blades are flattened.

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[1] Z. landw. Oesterr. 1901, **4**, 151.

[2] J. pharm. chim. 1895, [6], 83.

[3] Acad. roy. Belge, classe sci. 1921, mem. [2], **6**, No. 6, 1.

[4] Loc. cit.

[5] Compt. rend. 1931, **192**, 525.

[6] Ann. chim. appl. 1928, **18**, 47.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

MICROSCOPIC STRUCTURE (Fig. 55).—The following description is of the leaf blade. The *lower (outer) epiderm* has more numerous stomata than Spring onions. These are sunken below the level of the adjoining longitudinally elongated epidermal cells which show distinct striations radiating from the guard cells. As in the onion, the cells of the *subepiderm* are mostly isodiametric or transversely elongated with faintly beaded walls. Oxalate crystals up to 35 μ, often slender, occur in the bases of the outer leaves. *Latex tubes, mesophyl,* and *upper (inner) epiderm* are the same as in the onion.

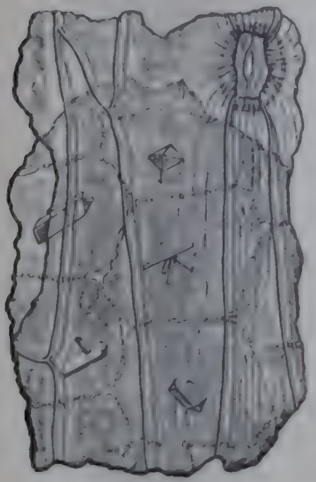

FIG. 55.—Leek. Outer leaf base in surface view showing outer epiderm with sunken stoma and subepiderm with crystals. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Bases of leaves thick but not forming a distinct bulb.

Epiderm cells striate, particularly about stomata; subepiderm of outer leaf bases containing crystals.

CHEMICAL COMPOSITION.—Dahlen[1] analyzed the bulb, roots, and leaves with the results (recalculated) as shown below together with an analysis of the edible portion by Agcaoili.[2]

COMPOSITION OF LEEK

	Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
	%	%	%	%	%	%	%
Dahlen:							
Bulbs........	87.67	2.71	0.23	7.39	0.44	1.12	0.88
Roots........	90.14	2.39	0.36	4.06	trace	1.56	1.49
Leaves.......	91.30	1.84	0.42	4.53	0.77	1.05	0.86
Agcaoili:							
Edible parts..	91.92	1.88	0.55	3.63	....	1.10	0.92

Mineral Constituents.—Dahlen[1] found in the samples of bulbs, roots, and leaves respectively: phosphoric acid 0.150, 0.196, and 0.081; organic sulphur 0.056, 0.067, and 0.56 per cent.

Minor Mineral Constituents. *Copper.*—Bulb, fresh 2.5, dry basis 22.7; leaves, fresh 5.0, dry basis 54.3 mg. per kilo (Guérithault).[3]

Aluminum.—Plant 201 mg. per kilo, dry basis (Bertrand and Lévy).[4]

Zinc.—Root-free 2.3 mg. per kilo, fresh basis (Bertrand and Benzon).[5]

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[1] Landw. Jahrb. 1874, **3**, 723.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] Compt. rend. 1920, **171**, 196.

[4] Bul. soc. hyg. aliment. 1931, **19**, 359.

[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

LEAVES OF THE BUCKWHEAT FAMILY

(*Polygonaceæ*)

This family, in addition to a common cereal (buckwheat) and one of the most ancient drugs (rhubarb), contributes several acid leaf vegetables of which garden rhubarb, with edible petioles, and several species of sorrel, with edible petioles and leaf blades, are the best known.

Characteristics other than their content of acid are the glandular epidermal *hairs*, *papillæ*, and the mesophyl *crystals* of calcium oxalate.

Although the petioles of rhubarb are rich in *oxalic acid*, more than half of which is soluble in water, this acid is largely combined and their acid taste is largely due to *malic acid*.

RHUBARB

Rheum Rhaponticum L.

Fr. Rhubarbe. Sp. Ruibarbo. It. Rabarbaro. Ger. Rhabarber.

Southern Siberia is believed to be the home of garden rhubarb. As in celery, chard, and angelica, the petiole is the part of chief value. In preparing for cooking, the skin is commonly stripped off and rejected; on the other hand the bases of the leaf ribs, to which some of the leaf blade may adhere, are utilized. Because of its high acidity, the petiole is treated more as an acid fruit than as a vegetable, being stewed and eaten as a sauce with a liberal addition of sugar, or made into pies—hence the name " pie plant." The leaf blade may be cooked as greens, but its possible toxicity, as noted under Chemical Composition, deserves notice.

MACROSCOPIC STRUCTURE.—The *leaves* are radical and have long (25 cm. or more), thick (often 2 to 3 cm.) petioles with thin, more or less united stipules. They are gathered by pulling, the separation from the crown being below the stipules where the petiole is thin. On the under (outer) side the *petiole* is rounded and has indistinct ribs corresponding to the main leaf branches which usually are five; on the upper (inner) side it is slightly grooved. It is smooth throughout. Above, it is green, red, or mottled; at the base it is white or pink. A cross section held to the light shows numerous vascular bundles dotting the field.

MICROSCOPIC STRUCTURE. Petiole (Figs. 56, 57, and 58).—A cross section of the petiole (Fig. 56) shows (1) an *epiderm* (*ep*) of strongly elongated (except about the stomata and hairs) cells with striated cuticle, distinct nucleii, and often red sap, also stomata and glandular hairs; (2) *collenchyma* (*col*), several cells thick, with strongly thickened angles, containing chlorophyl grains (*ch*); (3) ground tissue of *parenchyma* (*p*), containing chlorophyl grains, and *crystal cells* (*cr*), each containing a large calcium oxalate rosette; and (4) *vascular bundles.*

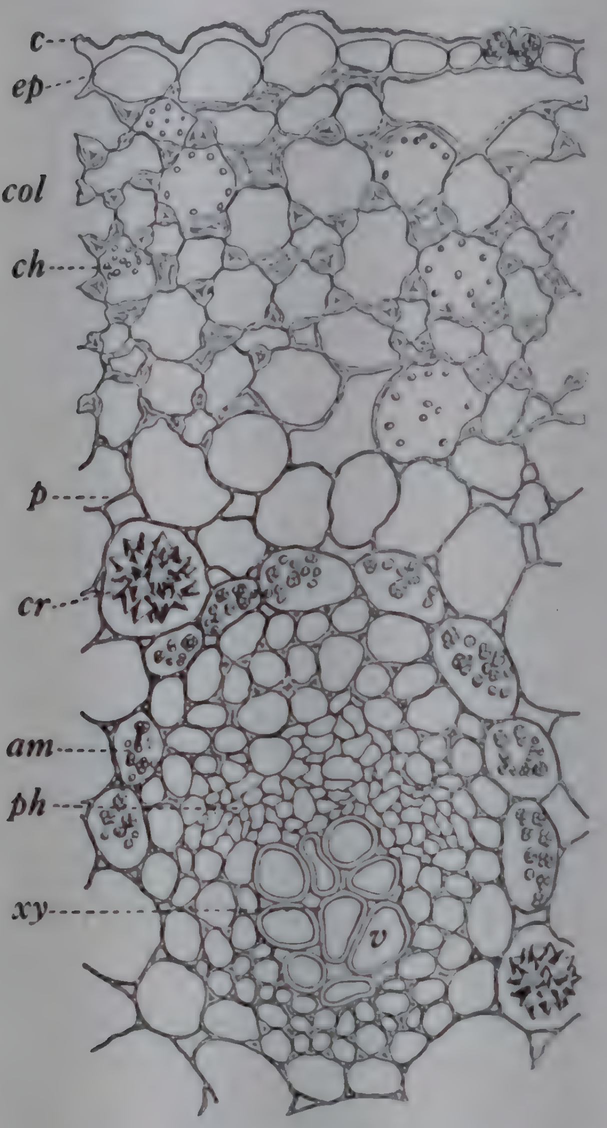

Fig. 56.—Rhubarb. Petiole in cross section. *ep* epiderm with stoma and *c* cuticle; *col* collenchyma with *ch* chlorophyl grains; *p* parenchyma of ground tissue; *cr* calcium oxalate rosette; *am* starch sheath of vascular bundle; *ph* phloem; *xy* xylem with *v* vessels. × 160. (K.B.W.)

The *glandular hairs* (Fig. 58, t^1, t^2), most noticeable in surface preparations, have multicellular cup-shaped heads and often double basal cells. *Papillæ,* similar to those on the leaf blade, are sometimes present on the petiole near the junction with the leaf blade.

The large *vascular bundles* (Figs. 56 and 57) are encircled on the outer side by a *starch sheath* (*am*) with starch grains grouped in aggregates up to 12 μ. Within this sheath the cells are collenchymatously thickened at the angles. The phloem consists of typical *sieve tubes* (*s*) and *companion cells* (*c*). The xylem elements are chiefly *spiral vessels* (*sp*), *annular* (*an*) and *reticulated* (*ret*) forms being of less frequent occurrence.

Stipules.—The *epiderm* on both sides consists of irregularly arranged, nearly isodiametric cells and numerous stomata.

Leaf Blade (Fig. 59).—The *lower* (*outer*) *epiderm* between the veins consists of sinuous-walled cells, stomata, and glandular hairs like those of the petiole, while over the veins the cells are straight-walled and elongated with numerous papillæ; the *upper epiderm* differs from the lower in that neither glandular hairs nor papillæ are present. *Mesophyl* elements are chlorophyl parenchyma, vascular bundles, and cells with oxalate rosettes.

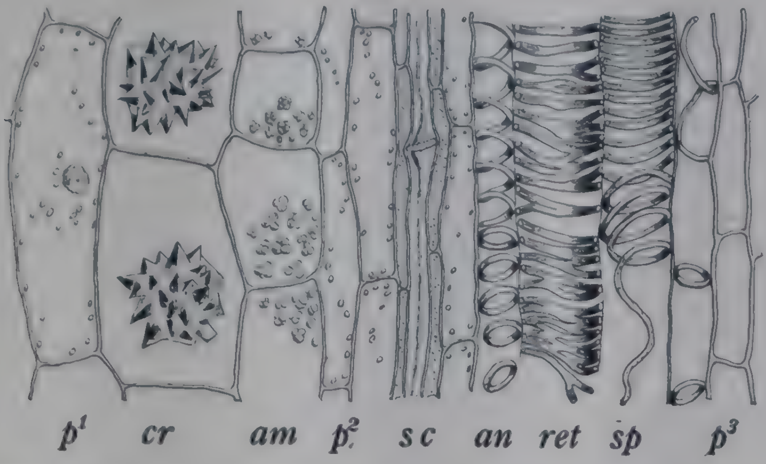

FIG. 57.—Rhubarb. Petiole in radial longitudinal section showing elements of vascular bundle and adjacent tissues. p^1, p^2, p^3 parenchyma; *cr* crystal cells; *am* starch sheath; *s* sieve tubes; *c* companion cells; *an* spiral vessels running into annular; *ret* reticulated vessel; *sp* spiral vessel. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Petiole rounded below, grooved above; cross section dotted with vascular bundles.

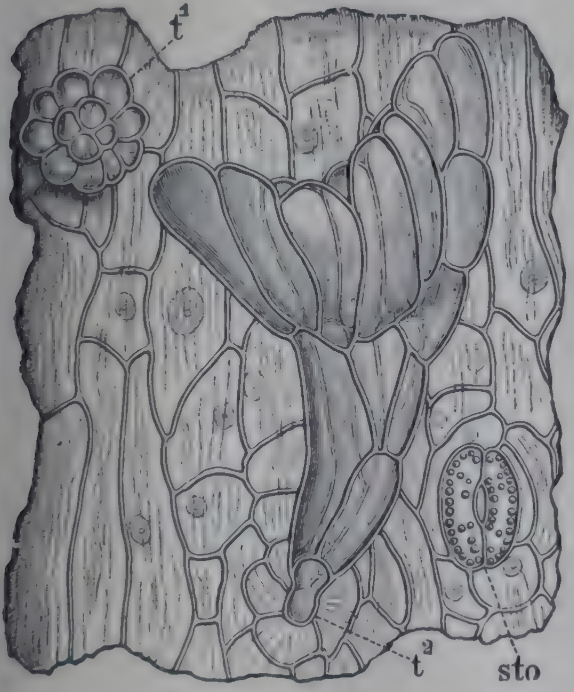

FIG. 58.

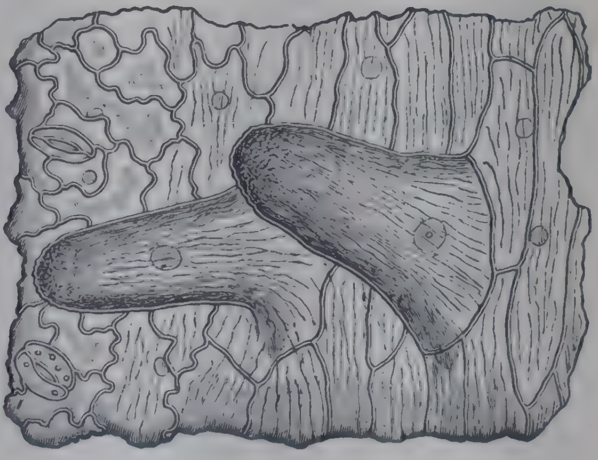

FIG. 59.

FIG. 58.—Rhubarb. Epiderm of petiole in surface view. *sto* stoma, t^1 immature and t^2 mature glandular hairs. × 160. (K.B.W.)

FIG. 59.—Rhubarb. Lower epiderm of leaf blade showing wavy-walled cells, stomata, and two papillæ arising from straight-walled cells over vein. × 160 (K.B.W.)

Epiderm of elongated cells and glandular hairs with multicellular heads and double basal cells; collenchyma strongly thickened; ground tissue parenchymatous with crystal cells; vascular bundles with starch sheath and collenchyma-like cells; xylem chiefly spiral vessels, annular and reticulated forms less numerous.

CHEMICAL COMPOSITION.—The petiole and leaf blade are remarkable for their high acidity and the occurrence of oxalic acid in different combinations.

The usual proximate analysis is of little value aside from showing the high water content, acids and sugar, notwithstanding the differences in their organoleptic and nutritional values, being included in the nitrogen-free extract. A summary of 2 such analyses compiled by Atwater and Bryant,[1] also 3 by v. Schleinitz[2] and one by Maue,[3] follow:

COMPOSITION OF RHUBARB

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Atwater and Bryant:							
Edible part (petiole)							
Min.	92.7	0.3	....	0.1	2.9*	....	0.6
Max.	96.1	0.8	....	1.2	4.4*	....	0.9
Aver.	**94.4**	**0.6**	....	**0.7**	**3.6***	**1.1†**	**0.7**
v. Schleinitz:							
Peeled petiole	94.74	0.69	0.33	0.10	3.01	0.58	0.88
Unpeeled petiole	94.07	0.74	0.40	0.11	3.30	0.84	0.94
Leaf blade	88.54	3.99	3.43	0.71	4.35	1.04	1.37
Maue:							
Leaf (blade?)	91.14	2.37	2.25	0.53	3.91	0.81	1.61

* Includes fiber. † 1 sample.

Culpepper and Caldwell[4] and Culpepper and Moon[5] have studied the influence of age and season on the composition of rhubarb. Selected results are given in the table on the next page.

Acids.—Attention has been directed chiefly to the *oxalic acid* of rhubarb, although Angerhausen[6] states that the free acid is chiefly *malic*. During the World War when every possible source of nutriment was utilized in Germany, rhubarb leaves were first recommended for greens, then their alleged toxicity was given due attention.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Landw. Jahrb. 1918, **52**, 131.

[3] Z. Unters. Nahr.-Genussm. 1920, **40**, 345.

[4] Plant Physiol. 1932, **7**, 447.

[5] J. Agr. Res. 1933, **46**, 387.

[6] Z. Unters. Nahr.-Genussm. 1920, **39**, 81.

Composition of Rhubarb Petioles (Culpepper and Caldwell)

	Age	Length	Solids		Acids as malic	Sugars, total	Polysaccharides*	Tannin	Nitrogen		
			Total	Alcohol sol.					Total	Nitrate	Amino
	days	cm.	%	%	%	%	%	%	%	%	%
Series I:											
Apr. 21	10	5–10	5.21	2.96	0.999	0.65	0.55	0.096	0.211	0.014	0.045
May 19	38	30–35	5.71	2.80	0.884	0.42	0.67	0.086	0.178	0.067	0.027
June 15	65	35–45	6.52	2.96	0.749	0.66	0.70	0.110	0.130	0.100	0.020
Series III:											
July 6. .	5	10–15	6.57	3.44	1.520	0.40	0.76	0.168	0.267	0.017	0.071
" " . .	13	30–40	6.15	3.20	1.380	0.60	0.77	0.123	0.197	0.026	0.057
" " . .	60	50–70	6.82	2.96	0.781	0.56	0.75	0.265	0.121	0.073	0.010

* Acid hydrolyzable.

Van Itallie and Lemkes,[1] referring to a fatal case of poisoning from eating the greens, state that in the leaf blade the content of anhydrous oxalic acid varies from 0.30 to 1.11 per cent and in the petiole from 0.44 to 0.99 per cent, also that the toxic dose is lower than usually stated. Arbenz[2] found 0.32 per cent of *oxalic acid* in the petiole, and Viehoever, Kunke, and Mastin[3] 0.39 per cent in the petiole and 0.84 per cent in the leaf blade.

Angerhausen states that it is not the free acid but the soluble acid potassium salt, KHC_2O_4, that is poisonous. By adding 0.3 to 0.6 gram of calcium carbonate per 100 grams of petioles and leaf blades respectively, toxicity is destroyed, and by treating with hot water the toxic principle may be extracted. Sodium carbonate and bicarbonate, also magnesium carbonate, do not accomplish the purpose, since the compounds formed or dissolved are also toxic.

The following are his extreme results on 4 samples:

	Petioles	Leaf blades
	%	%
Water-soluble oxalic acid. . . .	0.23–0.32	0.46–0.51
Water-insoluble oxalic acid. . .	0.16–0.22	0.13–0.21
Total oxalic acid.	0.39–0.50	0.59–0.72

Maue[4] found in rhubarb 0.368 per cent of soluble anhydrous oxalic acid and 0.01 to 0.05 per cent of hydroxymethylanthraquinone, free and combined, none of which amounts in his opinion could cause illness. He further showed that the acid of the stomach does not dissolve the oxalic acid of the insoluble compounds. These results, as well as experiments with men, led him to conclude that any ill effects must be due to other substances, possibly saponins.

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[1] Pharm. Weekbl. 1917, **54**, 1234.

[2] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[3] Science 1917, **46**, 546.

[4] Loc. cit.

Mineral Constituents.—An ash analysis by Maue[1] shows the following constituents derived largely from the plant: potash 24.25, soda 1.28, lime 6.64, magnesia 4.21, phosphoric acid 5.89, and sulphuric acid 1.96 per cent. In addition there were present constituents derived largely from spattered dirt as follows: ferric oxide 2.52, alumina 14.88, silica insoluble in sodium carbonate 15.48, and silica soluble in sodium carbonate 9.19 per cent. The undetermined matter, 6.93 per cent, included the carbon dioxide combined with the excess of bases over the mineral acids.

Minor Mineral Constituents. *Iron.*—Petiole 8.6 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Aluminum.—Leaf blade 166 mg. per kilo, dry basis (Bertrand and Lévy).[3] Petiole 32 mg. per kilo, dry basis (Bertrand and Lévy).[4]

Manganese.—Petiole 30.6 mg. per kilo, dry basis (Peterson and Skinner).[5]

Copper.—Petiole 0.5 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Petiole 1.6 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

GARDEN SORREL

Rumex Acetosa L.

Fr. Oseille. Sp. Acedera. It. Acetosa. Ger. Sauerampfer.

Belleville dock and sorrel dock are other names for this species. It is a native of Europe but has escaped from cultivation in parts of the United States. Like those of its near relative common or sheep sorrel its root leaves are distinctly acid, which adds zest to the vegetable when used as a pot herb.

Spinach dock or herb patience (*R. Patientia* L.) has leaves tapering at the base, and French sorrel (*R. scutotus* L.) has broad, heart- or halberd-shaped leaves. The young leaves of curled dock (*R. crispus* L.), a troublesome weed, are occasionally gathered for greens.

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[1] Loc. cit.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Compt. rend. 1931, **192**, 525.

[4] Bul. soc. hyg. aliment. 1931, **19**, 359.

[5] J. Nutrition 1931, **4**, 419.

[6] J. Biol. Chem. 1929, **82**, 465.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

MACROSCOPIC STRUCTURE.—The *leaves* are halberd-shaped, often 8 cm. or more long, blunt at the apex but with sharp lobes at the base. They are borne on long but slender petioles.

MICROSCOPIC STRUCTURE. Petiole.—The tissues are (1) *epiderm* of longitudinally elongated cells, glandular hairs and papillæ as on leaf blade, and between the ribs numerous stomata; (2) *collenchyma*, occurring only on angles and ribs; (3) *ground parenchyma*, some of the cells with rosettes of slender oxalate crystals; and (4) *fibro-vascular bundles* with spiral, annular, and reticulated vessels, the spiral predominating.

Leaf Blade.—The *lower* (*outer*) *epiderm* between the veins consists of wavy-walled cells, glandular hairs with usually four-celled head and two-celled stalk, and numerous stomata, while over the veins it consists of elongated cells and papillæ, both with numerous minute warts. The *upper epiderm* differs from the lower in that the walls are not so wavy and papillæ and warts are lacking. Calcium oxalate rosettes and fibro-vascular bundles like those of the petiole occur in the *mesophyl*.

CHIEF STRUCTURAL CHARACTERS.—Leaf halberd-shaped, obtuse; petiole long.

Petiole and leaf blade with glandular epidermal hairs and papillæ; rosettes of slender oxalate crystals in the inner tissues.

CHEMICAL COMPOSITION.—Dahlen[1] found as follows:

Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
% 92.18	% 2.42	% 0.48	% 3.44	% 0.37	% 0.66	% 0.82

Acids.—Arbenz[2] found 0.27 per cent of *oxalic acid.*

Minor Mineral Constituents. *Copper.*—Leaves 2.4 mg. per kilo, fresh basis (Guérithault).[3]

Zinc.—Whole leaf 2.2 mg. per kilo, fresh basis (Bertrand and Benzon).[4]

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[1] Landw. Jahrb. 1874, **3**, 723.

[2] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[3] Bul. soc. hyg. aliment. 1927, **15**, 386.

[4] Ibid. 1928, **16**, 457.

LEAVES OF THE GOOSEFOOT FAMILY

(*Chenopodiaceæ*)

Three leaf vegetables of this family, spinach, beet, and chard (the last two being varieties of *Beta vulgaris*), are popular pot herbs.

COMPARATIVE MACROSCOPIC STRUCTURE.—Only the leaves and petioles of spinach are edible, the roots being of no value. Beets are commonly cultivated for the roots, the tops and undeveloped roots being a by-product obtained in thinning. The enlarged petiole of chard is the part valuable as food. The leaves of all the members of the group spring directly from the roots.

COMPARATIVE MICROSCOPIC STRUCTURE.—The *epiderms* of the leaf have wavy-walled cells and jointed *hairs* with rounded end cells. In spinach the end cell is often much enlarged (capitate) and unicellular hairs are present; in beet and chard the end cells are seldom enlarged and unicellular hairs are absent or rare. *Crystal sand* in large aggregates occurs in the mesophyl of all three members of the group.

COMPARATIVE CHEMICAL COMPOSITION.—The *proteins* of spinach have been the subject of a special investigation. This vegetable is accordingly one of the few leaf vegetables that have been studied beyond making proximate and ash analyses. As much as 70 per cent of the total nitrogen exists as proteins.

SPINACH

Spinacia oleracea L.

Fr. Espinard. Sp. Espinaca. It. Spinace. Ger. Spinat.

Persia, according to De Candolle, is the home of common spinach. It is possibly a cultivated form of *S. tetrandra* Stev. which grows wild in Persia and adjoining states and is used there as a vegetable. The two races, one with round the other with prickly seed, are regarded as belonging to the same species.

Spinach was introduced into Europe in the fifteenth century. Many regard it as the best of all greens, and nutritionists strongly recommend it as a food for children. It is preeminently a cool-weather plant, hence it is grown in the Fall and Spring. Enormous quantities are shipped north by southern truck gardeners during the colder months.

MACROSCOPIC STRUCTURE.—The tender young *stems* and rather thick entire *root leaves* with their succulent petioles are edible. The petiole is hollow, grooved on the upper side, and rounded heart-shaped in cross section. Although the leaf is ordinarily halberd-shaped, ovate and other forms are not uncommon; it is smooth with a prominent midrib and several main veins.

MICROSCOPIC STRUCTURE. Stem.—The elements are practically the same as those of the petioles but there are more *collenchyma* and *fibro-vascular bundles.* Over the collenchyma bundles the *epidermal cells* are longitudinally elongated; between these the cells are more or less isodiametric, interspersed with stomata.

Petiole.—The tissues are: (1) *epiderm* with cells, stomata, and hairs practically the same as those of the leaf proper; (2) *hypoderm* of collenchyma in six bundles—one in each edge, one in the center of the dorsal rib, and three alternating with the foregoing—separated by chlorophyl parenchyma; (3) *cortex*; (4) hollow *central cylinder* in which are three collateral fibro-vascular bundles with xylem, consisting chiefly of closely wound spiral vessels, on the inner side.

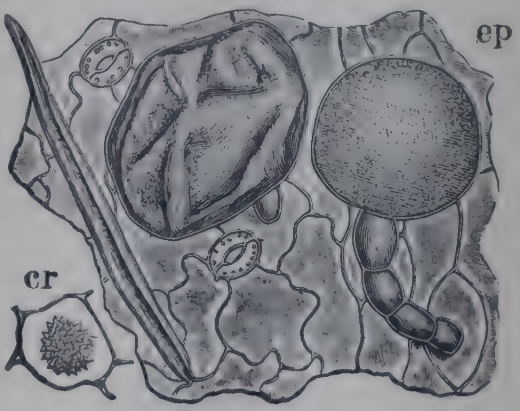

FIG. 60.—Spinach. Leaf in surface view. *ep* lower epiderm with one unicellular and two capitate hairs; *cr* crystal cell of mesophyl. × 160. (K.B.W.)

Leaf Blade (Fig. 60). *Lower (Outer) Epiderm (ep).*—Over the ribs and veins the cells of the lower epiderm are elongated and have straight walls; in other parts they are sinuous-walled. The stomata often have horns.

Capitate hairs occur both on the veins and between them. The stalks are jointed, the upper cells being often swollen, and sometimes strongly curved. The head varies greatly in size and turgescence. *Unicellular hairs* occur chiefly between the veins, reaching often over 500 μ in length. They are straight, stiff, narrowed at the base, and have walls broader than the lumen. Both forms of hairs are particularly abundant on the young leaves, but during growth the capitate forms shrivel and disappear, and the unicellular forms often are broken off.

Mesophyl.—This consists chiefly of loosely arranged chlorophyl cells and here and there crystal cells (*cr*), each with a large aggregate of minute crystals (crystal sand). Sometimes there is more than one aggregate in a cell, but in any case they easily break down. A *palisade layer* is present beneath the upper epiderm.

Upper (Inner) Epiderm.—This differs from the lower epiderm in that the cell walls are straight or not so sinuous, the stomata are not so numerous, and horns on the stomata are infrequent.

CHIEF STRUCTURAL CHARACTERS.—Petioles and stem succulent, hollow; petioles channeled. Leaves more or less halberd-shaped, smooth.

Petioles and stem with collenchyma bundles and fibro-vascular bundles; vessels mostly spiral. Epiderms of leaf with straight- and sinuous-walled cells, stomata, and hairs, both capitate and unicellular. Mesophyl with aggregates of small crystals.

CHEMICAL COMPOSITION.—A summary of 3 analyses, as compiled by Atwater and Bryant,[1] also analyses by v. Schleinitz[2] and by Chung and Ripperton[3] follow:

COMPOSITION OF SPINACH

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
A. and B.:						
Min	91.6	1.8	0.2	3.1*	0.7	1.9
Max	92.8	2.4	0.5	3.4*	1.0	2.4
Aver	**92.3**	**2.1**	**0.3**	**3.2***	**0.9**	**2.1**
v. Schleinitz	93.34	2.28†	0.27	1.74	0.50	1.87
C. and R.	93.40	2.12	0.08	2.27	0.63	1.50

* Includes fiber. † Pure protein 2.10%.

The results in the table on the next page are by Geise,[4] who made an extensive study of spinach for canning.

Changes in Composition During Storage.—Geise[4] found that spinach stored at −3° C. gained slightly in moisture, whereas stored at 5 and at 16 to 21° C. it lost moisture. During storage there was a loss of both total and reducing sugars, the greater losses being for the higher temperatures.

Proteins.—Osborne, Wakeman, Leavenworth, and Nolan,[5] by grinding the green leaves with water, centrifuging, filtering, and addition of alcohol, secured a bulky precipitate which after extraction with alcohol and ether was of nearly pure proteins combined or admixed with

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Landw. Jahrb. 1918, **52**, 131.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[4] Maryland Agr. Exp. Sta. 1930, Bul. **320**.

[5] J. Biol. Chem. 1920, **42**, 1.

COMPOSITION OF SPINACH SHOWING SEASONAL VARIATION (GEISE)
(Results on dry edible basis)

	Water	Solids	Protein	Sugars, total*	Sugars, red.*	Sucrose*	Starch, etc.†	Fiber	Alcohol extract
	%	%	%	%	%	%	%	%	%
Fall crop:									
Oct. 9......	89.70	10.30	32.75	6.80	2.21	4.59	11.5	3.93	26.06
Oct. 15......	89.12	10.88	29.75	4.81	2.41	2.40	11.0	4.32	30.61
Oct. 22......	88.08	11.92	29.13	7.33	2.10	5.23	11.1	3.07	30.93
Oct. 30......	86.49	13.51	28.38	17.21	2.59	14.62	10.0	2.84	36.58
Nov. 6......	86.78	13.22	24.87	9.64	3.12	6.52	11.0	3.27	34.44
Nov. 13......	86.11	13.89	27.94	18.40	2.20	16.20	11.0	2.33	51.68
Nov. 20......	85.57	14.43	28.81	11.25	3.11	8.14	9.1	3.72	38.74
Nov. 27......	82.05	17.95	27.19	19.51	1.92	18.59	9.1	2.76	44.44
Overwintered:									
Mar. 27......	87.40	12.60	24.07	10.14	3.68	6.46	12.3	3.37	44.90
Apr. 2......	87.30	12.70	30.25	13.01	4.03	8.98	12.9	3.00	33.98
Apr. 9......	87.10	12.90	29.25	7.17	2.52	4.65	14.5	4.22	32.26
Spring crop:									
May 8......	90.70	9.30	30.56	5.38	1.49	3.89	13.0	3.99	31.88
May 10......	89.12	10.88	21.25	8.55	2.90	5.65	13.5	3.54	34.54
May 14......	90.15	9.85	29.81	4.82	1.47	3.35	12.2	......	......
May 21......	90.28	9.72	28.44	6.40	2.81	3.59	12.0	5.67	31.63
Leaves May 21:									
Young.......	89.81	10.19	46.31	6.62	3.55	3.07	11.7	4.33	32.03
Mature......	88.90	11.10	31.81	7.43	2.81	4.62	12.7	3.94	42.79
Old..........	86.90	15.10	26.44	8.08	1.90	6.18	13.5	3.43	52.88

* As dextrose. † Non-saccharine, acid-hydrolyzable substances calculated as dextrose.

a small amount of carbohydrate but containing no nucleic acid. Although difficultly soluble in cold dilute alkali, it dissolved in boiling 60 per cent alcohol containing 0.3 per cent of sodium hydroxide from which on neutralizing it was precipitated in a colloidal form, containing about 15.25 per cent of nitrogen, readily soluble in dilute acid or alkali. The filtrate from the alcohol precipitate contained the water-soluble cell constituents forming 50 per cent of the leaf solids including proteose, coagulable proteins, and 28 per cent of non-protein organic matter.

The yield of proteins, representing 67 per cent of the total nitrogen, is summarized as follows: colloidal protein 21.2, proteose 1.7, coagulable protein 1.4, total proteins 24.3 per cent of leaf solids.

Jones, Gersdorff, and Moeller[1] found in "spinach protein"—evidently the colloidal protein described above—cystine 2.72 and tryptophane 1.85 per cent. In spinach protein Fürth and Lieben[1] found *tryptophane* 4.3 per cent.

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[1] J. Biol. Chem. 1924, **62**, 183.

Cribnall[2] describes a method of separate extraction of vacuole and protoplasmic matter. The cells are first plasmolyzed by ether, butyl alcohol, or some other organic substance, then the vacuole contents removed, partly by direct pressing, the remainder by soaking in 0.002 normal hydrochloric acid and pressing without rupturing the cells. The residue is ground with water and the protoplasmic contents of the cells removed as a colloidal solution and flocculated with acid. Extraction of the colloidal mass with alcohol and ether removes most of the impurities from the " cytoplasm proteins." By this process Cribnall[3] isolated from the cytoplasm of spinach leaves a protein " *spinacin*," containing 16.25 per cent of nitrogen and forming about one-fifth of the total protein matter in the cytoplasm. Spinacin is insoluble in water and salt solution but soluble in a slight excess of acid or alkali. It contains no carbohydrate groups.

The following table gives results by Cribnall:

	Cytoplasm protein		Vacuole protein	
	In total N	In protein	In total N	In protein
	%	%	%	%
Amide N	6.94	1.14	7.91	1.11
Humin N	2.06	0.33	2.56	0.36
Basic N	26.59	4.32	22.06	3.11
Other N	64.41	10.46	67.47	9.44
	100.00	16.25	100.00	14.02

After hydrolysis, spinacin yielded by Van Slyke's method amide nitrogen 6.93; humin nitrogen in acid 0.76, in lime 1.46, in amyl alcohol 0.25; cystine nitrogen 1.27; arginine nitrogen 13.8; lysine nitrogen 9.63; histidine nitrogen 3.89; amino nitrogen in filtrate 58.09; and non-amino nitrogen in filtrate 2.58 per cent. In terms of amino acids, the protein contained arginine 6.95, lysine 8.19, and histidine 2.34 per cent.

Fat.—From fresh spinach Speer, Wise, and Hart[4] isolated fatty acids equivalent to 0.808 gram per 100 grams of the original material, of which

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[1] Biochem. Z. 1921, **122**, 58.

[2] J. Biol. Chem. 1923, **55**, 333.

[3] Ibid. 1924, **61**, 303.

[4] Ibid. 1929, **82**, 105.

47 per cent was combined as glycerides and 53 per cent was free. The solid acids consisted chiefly of palmitic and stearic acids, together 26.5 per cent, and cerotic acid 3 per cent. The liquid acids consisted of linolenic acid 12.7, linolic acid 34.7, and oleic acid 26.3 per cent.

Sterols, Alcohols, and Hydrocarbons.—Heyl, Wise, and Speer,[1] Hart and Heyl,[2] Heyl and Larsen,[3] and Larsen and Heyl[4] studied the constituents of the unsaponifiable fraction of spinach fat. The substances isolated include (1) three isomeric sterols, α-, β-, and *γ-spinasterol* ($C_{28}H_{46}O$); (2) two alcohols, *n-tetracosanol* and *n-hexacosanol*; (3) a hydrocarbon ($C_{20}H_{42}$), possibly petrosilane (laurane); and (4) an oily compound ($C_{27}H_{54}O$). On hydrogenation the three sterols yielded first spinastenols, analogous to ergostenols, and finally the same reduction product, spinastanol ($C_{28}H_{50}O \cdot \frac{1}{2}H_2O$). They showed melting point 172.5°, 145 to 148°, and 159 to 160° C., and specific rotation at 20° C. -3.7, $+7.65$, and 0° respectively.

Acids.—*Oxalic acid*, doubtless combined as calcium oxalate, has been determined in five laboratories with the following results, calculated on the fresh basis: Viehoever, Kunke, and Mastin[5] 0.82, Arbenz[6] 0.29, Esbach[7] 0.32, Ryder[8] 0.49 to 0.69, and Nelson and Mottern[9] 0.31 per cent. Nelson and Mottern also separated *citric acid* and a small amount of *malic acid*.

Saponins.—Although Dafert[10] found for the sun-dried root a hemolytic index due to saponin of 1 : 1000 and for the over-dried root 1 : 400, for the stem and leaf it was small.

Colors.—Smith and Milner[11] state that the *carotene* of spinach is the β-form. Karrer and Schlientz[12] found in addition a trace of the α-form.

Mineral Constituents.—Wolff[13] found in the vegetable: potash 0.128 and soda 0.388 equivalent respectively to 11.6 and 35.3 per cent in the ash; Haskins[14] reports much less soda, although the amount relative to the potash is uncertain, owing to a misprint, the same percentage of potash as of ash being given.

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[1] J. Biol. Chem. 1929, **82**, 111.

[2] Ibid. 1932, **95**, 311.

[3] J. Am. Pharm. Ass. 1933, **22**, 510; J. Am. Chem. Soc. 1934, **56**, 942.

[4] J. Am. Chem. Soc. 1934, **56**, 2663.

[5] Science 1917, **46**, 546.

[6] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[7] Bul. gen. Ther. Med. Chir. 1883, **114**, 385.

[8] J. Home Econ. 1930, **22**, 309.

[9] J. Am. Chem. Soc. 1931, **53**, 1909.

[10] Z. Unters. Lebensm. 1930, **60**, 408.

[11] J. Biol. Chem. 1934, **104**, 437.

[12] Helv. Chem. Acta 1934, **17**, 7.

[13] Aschenanalysen.

[14] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

True, Black, and Kelly[1] brought about radical changes in the composition of the ash by heavy fertilization with different plant foods. In addition to single salts they used an " acid mixture," consisting of ammonium sulphate, acid phosphate, potassium muriate, dried blood, and tankage, and a " basic mixture " consisting of sodium nitrate, basic slag, potassium sulphate, dried blood, and tankage.

Analyses of Spinach Ash Showing Effects of Fertilizers
(True, Black, and Kelly)

Fertilizer	K_2O	Na_2O	CaO	MgO	Fe_2O_5	Al_2O_5	MnO	P_2O_5	SO_3	SiO_2
	%	%	%	%	%	%	%	%	%	%
Control.......	41.59	4.40	5.51	6.67	0.44	3.05	0.12	6.43	2.51	28.00
$NaNO_3$........	26.18	17.55	5.57	5.67	0.65	3.06	0.18	5.17	2.21	22.57
NaCl.........	16.87	26.00	5.18	6.60	0.41	2.61	0.09	5.59	2.11	17.42
Na_2SO_4.......	44.01	3.82	4.01	6.43	0.39	3.00	0.10	6.23	3.62	22.80
KCl..........	37.13	8.66	5.32	9.51	0.40	2.77	0.17	6.40	2.55	24.34
$CaCO_3$........	33.66	7.95	5.89	5.33	0.51	2.43	0.14	4.58	2.20	37.26
Acid phosphate	29.92	10.05	5.28	6.22	0.42	3.27	0.19	6.87	2.48	33.38
Acid mixture...	42.20	3.79	4.66	6.46	0.49	3.16	0.24	5.44	2.82	26.23
Basic mixture..	46.77	3.55	5.22	7.20	0.54	2.42	0.16	7.10	2.85	21.56
Manure.......	44.91	2.07	3.87	7.32	0.51	2.35	0.07	4.97	2.21	20.57

Minor Mineral Constituents. *Iron.*—Plant, partly wilted, 38 mg. per kilo. (Sherman).[2] Plant 43 mg. per kilo, fresh basis (Bunge quoted by Sherman).[2] Plant 20 mg. per kilo, fresh basis (Baldoni quoted by Sherman).[2] Edible part 27 to 87 mg. per kilo, fresh basis (Lichtin).[3] Plant 66 mg. per kilo, fresh basis (Peterson and Elvehjem).[4] Plant, 4 samples, 34.8 to 57.9 mg. per kilo, fresh basis (Toscani and Reznikoff).[5] Plant, 13 samples, edible portion 275 to 1750, aver. **956** mg. per kilo, dry basis (Remington and Shiver).[6]

Blunt and Otis[7] have shown that the loss of iron on boiling reaches 50 per cent, being greater than in other vegetables examined.

Aluminum.—Plant 91 to 104 mg. per kilo, dry basis (Bertrand and Lévy).[8]

Manganese.—Plant, 12 samples, 52.5 to 253.3, aver. **141.2** mg. per kilo, dry basis (Remington and Shiver).[6]

[1] J. Agr. Res. 1919, **16**, 15.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **85**.

[3] Am. J. Pharm. 1924, **96**, 361.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Nutrition 1934, **7**, 79.

[6] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[7] J. Home Econ. 1917, **9**, 213.

[8] Bul. soc. hyg. aliment. 1931, **19**, 359.

Copper.—Plant, fresh 1.8, dry basis 18.3 mg. per kilo (Guérithault).[1] Plant, 14 samples, 5.5 to 19.9, aver. **10.7** mg. per kilo, dry basis (Remington and Shiver).[2] Plant 1.2 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[3]

Zinc.—Whole leaf 6.2 mg. per kilo, fresh basis (Bertrand and Benzon).[4]

Iodine.—Plant none. (Winterstein).[5]

BEET GREENS

Beta vulgaris L. var. *crassa* Alef.

Fr. Betterave. Sp. Acelga. It. Bietola. Ger. Rothe Rübe.

The following description is of plants, obtained in thinning, with roots about 1 cm. in diameter.

MACROSCOPIC STRUCTURE.—The *root leaves*, the only ones to appear during the first year, are smooth, crenate, with a prominent midrib and several primary veins joining the midrib at an acute angle on the outer (lower) side and extended along it and the *petiole* as ridges. The midrib on the inner (upper) side extends as a single ridge in the groove of the petiole. In red beets the ribs and nerves of the leaf and the entire petiole are commonly red, while the leaf blade between the nerves is either bronze-red or green.

MICROSCOPIC STRUCTURE. Petiole.—The *epiderm* on the dorsal ridges and between them corresponds with that on the veins and the surface between the veins of the leaf blade respectively; in the grooves, however, there is a tendency to longitudinal elonation of the cells. A *collenchyma bundle* occurs under each of the ridges on the outer side and the single ridge on the inner side. The *cortex* consists of *parenchyma* and *crystal cells* in longitudinal rows containing crystal sand in masses often larger than those of the mesophyl. A *starch sheath* bounds the inner row of cells of the cortex adjacent to the fibro-vascular bundles. A *fibro-vascular bundle* is situated directly beneath each dorsal ridge. The vessels are mostly spiral, annular, and spiral-reticulated.

Leaf Blade (Fig. 61).—Both *epiderms* are practically the same in structure, owing in part at least to their upright position during growth. On the veins the cells are straight-walled, elongated, end to end in rows; between the veins they are irregular in shape with wavy walls. Jointed *hairs* (*t*) occur on the midrib and veins of young leaves, less often between the veins, but usually shrivel up during further growth. *Stomata*, often with horns, are numerous between, but not on, the veins.

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[1] Compt. rend. 1920, **171**, 196.

[2] Loc. cit.

[3] J. Biol. Chem. 1929, **82**, 465.

[4] Bul. soc. hyg. aliment. 1928, **16**, 457.

[5] Z. physiol. Chem. 1918, **104**, 54.

Mesophyl.—In addition to typical *chlorophyl parenchyma*, there are present here and there chlorophyl-free cells containing *crystal sand* (*cr*), the exceedingly minute crystals being in small aggregates and these in turn consolidated into a large spherical mass showing with ordinary magnification little evidence of the component crystals into which they easily break up. *Palisade cells*, although present, are not strongly developed.

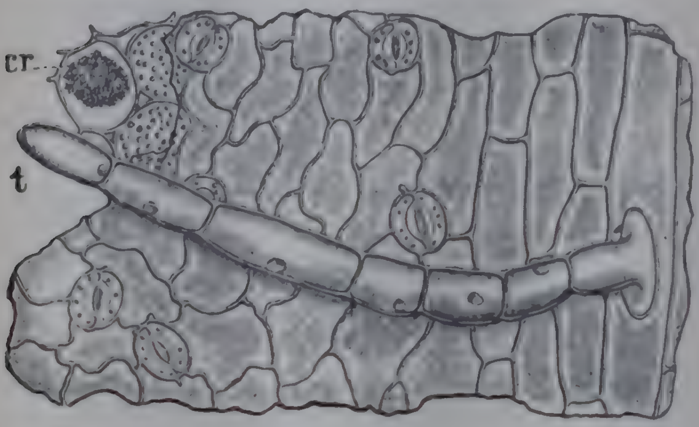

FIG. 61.—Beet. Leaf in surface view. Lower epiderm, with *t* hair arising over vein; *cr* cell with crystal sand from mesophyl. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Petiole with several ridges on outer (dorsal) side and a single ridge in the middle of the grove of the inner side. Leaf blade smooth, crenate, commonly with red midrib and veins and green or red intervals.

Epiderm on ridges of petiole and on midrib and veins of leaves of elongated, straight-walled cells and jointed hairs; on surface between veins and ridges of wavy-walled cells and stomata. Mesophyl and ground tissue of petiole with crystal cells containing masses of crystal sand. Petioles and midrib with a collenchyma bundle beneath each ridge and a fibro-vascular bundle beneath each outer ridge.

CHEMICAL COMPOSITION.—No data are at hand on the composition of the leaves and small roots of the garden beet obtained by thinning and used for greens. The analyses herewith of the leaves of

COMPOSITION OF BEET LEAVES

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Sugar beets:						
F. and W.......	87.89	2.36	0.24	6.48	1.07	1.96
Mangolds:						
v. Schleinitz						
Blade........	91.86	2.50*	0.42	2.83	0.75	1.63
Petiole.......	95.01	0.82†	0.10	2.42	0.78	0.87

* Pure protein 2.19%. † Pure protein 0.53%.

sugar beets by Failyer and Willard[1] and of mangolds by v. Schleinitz[2] probably represent the mature material separated from the roots when dug.

Nitrogenous Bases. *Betaine.*—Stanek and Domin,[3] who have examined plants of different families for betaine, state that its presence is confined to two families, *Chenopodiaceæ* and *Amarantaceæ.*

In the leaves of the sugar beet, Stanek[4] found 2.62 per cent of betaine, in the root 0.95 to 1.2 per cent. It appears to be concentrated in the parts of greatest physiological activity, serving probably as a step in nitrogen metabolism and not as reserve material. The seeds contain little or none.

Acids.—Ryder[5] reports in 2 samples of beet greens 0.62 and 0.75 per cent of *oxalic acid*, doubtless combined as calcium oxalate.

Carbohydrates.—Colin,[6] in accord with Girard and other earlier investigators, believes that *sucrose* is formed in the leaf of the beet and is thence translated to the root.

Colors.—The carotene isolated by Smith and Milner[7] from the leaves of the closely related sugar beet, Swiss chard, and spinach, like that from the leaves of the cauliflower, sunflower, and alfalfa, melted at 180.5° C. and was optically inactive, hence is classed as *β-carotene*, thus differing from α-carotene of carrot root.

Mineral Constituents.—Way and Ogston, Wolff, and others report analyses of the ash of mature (?) beet leaves of different varieties of beets differing greatly in percentages of the constituents. The range of potash is from less than 10 to over 30, of soda from less than 13 to over 31, of silica from about 1.5 to about 7, of chlorine from less than 3 to nearly 25 per cent, and so on. These differences are probably due in part at least to the kind of fertilizer used (see Spinach).

Minor Mineral Constituents. *Iron.*—Garden beet, leaves, 3 samples, 170 to 555, aver. **372** mg. per kilo, dry basis (Remington and Shiver).[8] Beet greens, root 18.3, tops 35.5 mg. per kilo, fresh basis (Peterson and Elvehjem).[9]

Manganese.—Garden beet, leaves, 3 samples, 143.0 to 205.2, aver. **182.7** mg. per kilo, dry basis (Remington and Shiver).[8]

Copper.—Garden beet, leaves, 3 samples, 9.0 to 19.7, aver. **13.5** mg. per kilo, dry basis (Remington and Shiver).[1] Beet greens, root 1.0, tops 0.9 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[2]

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[1] Kansas Agr. Exp. Sta. 1891, Bul. **32**, 225.

[2] Landw. Jahrb. 1918, **52**, 131.

[3] Z. Zuckerind. Böhmen 1910, **34**, 207.

[4] Z. physiol. Chem. 1911, **72**, 402.

[5] J. Home Econ. 1930, **22**, 309.

[6] Bul. assoc. chim. sucr. dist. 1921, **38**, 331.

[7] J. Biol. Chem. 1934, **104**, 437.

[8] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[9] J. Biol. Chem. 1928, **78**, 215.

Zinc.—Petiole 0.2 mg. per kilo, fresh basis (Bertrand and Benzon).[3]

CHARD

Beta vulgaris L. var. *Cicla* Moq. = *B. Cicla* L.

Fr. Carde-poirée. Sp. Hoja de Alcachofa. Ger. Krautstengel.

In addition to the fleshy-rooted beet, certain garden varieties have been developed solely for their leaves and petioles, which are used as greens, and others for their fleshy petioles, both being classed as var. *Cicla*. Chard or Swiss chard is the common name for the latter group.

MACROSCOPIC STRUCTURE.—The *petioles* are white or nearly so, crisp, grooved on the inner side and with strongly developed ridges on the outer side. In the lower half, they are thicker and more flattened than the petioles of beet root or celery. A row of bundles corresponding to the ridges is evident in cross section.

MICROSCOPIC STRUCTURE.—Except for more robust development the structure of the leaf and petiole is the same as described under Beet.

CHEMICAL COMPOSITION.—Chung and Ripperton[4] give the following analysis of "Swiss chard" or "Leaf Beet" grown and known in Hawaii under the Chinese name *tim-choi* and the Japanese name *to-jisa*:

Composition of Chard (Chung and Ripperton)

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
92.17	1.45	0.18	3.09	0.87	2.24

Colors.—See Beet Greens.

Mineral Constituents.—The above-named authors found: calcium 0.100, iron 0.0043, and phosphorus 0.024 per cent, also alkalinity of the ash 24.6 expressed as cubic centimers of normal acid per 100 grams fresh vegetable.

Minor Mineral Constituents. *Iron.*—Leaf base 40.2 mg. per kilo, fresh basis (Peterson and Elvehjem).[5]

Copper.—Leaf base 1.1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

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[1] Loc. cit.

[2] J. Biol. Chem. 1929, **82**, 465.

[3] Bul. soc. hyg. aliment. 1928, **16**, 457.

[4] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] Ibid. 1929, **82**, 465.

LEAVES AND STEMS OF THE AMARANTH FAMILY

(*Amarantaceæ*)

Only one genus, *Amarantus*, is represented.

PIGWEED

Amarantus spp.

Fr. Amarante. Sp. Amaranto. It. Amaranto. Ger. Amarant.

Common pigweed or red-root (*A. retroflexus* L.), a garden weed introduced from the tropics, is eaten as a pot herb in certain sections of the United States. Bailey[1] refers to *hon-toi-moi* (*A. gangeticus* L.) which he found of no special merit, but Chung and Ripperton[2] state that it is in demand in Hawaii under the name of Chinese spinach (Chinese: *yin-choi*; Japanese: *hiu* or *hiyu*). Blasdale[3] found both the weed and a cultivated form on sale in California. Specimens, described below, obtained by the writers from New York Chinatown, could not be distinguished from our garden weed.

MACROSCOPIC STRUCTURE.—The ovate, somewhat pubescent *stem leaves* are borne on long petioles. At the edible stage the *flowers* are undeveloped. The *root* is bright red.

MICROSCOPIC STRUCTURE. Stem.—This is made up of (1) *epiderm* of elongated cells with jointed, somewhat capitate hairs and occasional stomata, (2) *hypoderm* of collenchyma cells, (3) *cortex* with crystal sand cells and chlorophyl grains, and (4) *central cylinder* with crystal sand cells and vascular bundles.

Leaf.—Both *epiderms* consist of wavy-walled cells elongated and straight-walled over the veins, stomata, numerous jointed hairs with rounded sometimes enlarged end cell, and, rarely, unicellular hairs. Crystal sand is abundant in the *mesophyl*, especially along the veins.

Chief Structural Characters.—Stem leaves ovate, pubescent.

Epiderms of leaf with straight- and wavy-walled cells; hairs mostly jointed; mesophyl of leaf and ground tissue often with crystal sand.

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[1] Cornell Univ. Agr. Exp. Sta. 1894, Bul. **67**, 199.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**, 29.

CHEMICAL COMPOSITION.—Analyses of pigweed by Blasdale,[1] species not identified, grown near San Francisco, California, by Agcaoili,[2] stated to be *A. oleraceus*, grown in the Philippines, and by Chung and Ripperton,[3] stated to be *A. gangeticus*, grown in Hawaii, follow:

COMPOSITION OF PIGWEED

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Blasdale..........	91.52	2.61*	0.36	3.03†	0.92	1.56
Agcaoili						
Culitis..........	83.35	3.98	1.71	6.99	1.53	2.44
Colis maluco.....	81.38	4.50	0.57	8.39	2.00	3.16
C. and R..........	92.30	1.68	0.12	3.22	0.99	1.69

* Pure protein 1.67%. † Starch 0.50%.

Nitrogenous Bases. *Betaine.*—Stanek[4] reports 2.62 per cent in the leaves and 0.48 per cent in the roots of *A. retroflexus*. See also Beet Greens.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[4] Z. physiol. Chem. 1911, **72**, 402.

LEAVES AND STEMS OF THE ICE PLANT FAMILY

(*Aizoaceæ*)

The ice plant and purslane families are closely related, and plants of both by reason of their fleshy structure are adapted for desert regions or hot dry seasons. This fleshy condition also makes them suitable for greens.

In addition to New Zealand spinach, leaves of species of *Mesembryanthemum* are used as pot herbs.

NEW ZEALAND SPINACH

Tetragonia expansa Murr.

Fr. Épinard de la Nouvelle Zélande. Ger. Neuseeländischer Spinat.

This plant was introduced into Europe from New Zealand but is said to grow wild in other South Sea islands, also in Australia, Japan, and South America.

Botanically the plant is not related to common spinach although serving as a substitute for it. Leaves and tender ends of the branches may be cut from time to time during a long season.

MACROSCOPIC STRUCTURE.—The rounded-triangular, rather succulent *leaves* reach 10 cm. or more in length, the margined petiole constituting from one-third to one-quarter. There are three to six prominent veins on each side of the midrib with few or indistinct veinlets. The small (5 mm.) yellow-green *flowers*, with a four-lobed calyx but no peduncle, are borne in the axils of the leaves while still in the edible stage. Owing to the presence of the minute bladders, visible under a lens, the succulent stem and leaves glisten as if covered with frost.

MICROSCOPIC STRUCTURE. Stem.—Cross sections show (1) *epiderm* with oval bladders, two to three times the length of the cells; (2) *hypoderm* of thin-walled, elongated chlorophyl cells, several thick, passing into *collenchyma cells*, also several thick; (3) *cortex* of elongated parenchyma cells and occasional oxalate rosettes; (4) *starch sheath*; (5) *bundle ring* forming a rather narrow close zone; and (6) *pith* of large ground parenchyma and crystal cells.

Leaf.—The cells of the *outer* (*lower*) *epiderm* (Fig. 63, *iep*) are sinuous-walled except on the veins. Stomata are numerous. The *bladders* (Figs. 62 and 63), morphologically the same as hairs, some of which are borne on a narrow, jointed stalk, are especially numerous on the veins. They vary up to 0.5 mm. and usually have a short, pointed beak.

The *mesophyl* consists of typical loosely arranged cells rich in chlorophyl grains and here and there a cell containing an oxalate rosette (Fig. 63, *cr*). A *palisade layer* is present beneath the inner epiderm.

Cells of the *inner* (*upper*) *epiderm* have nearly straight walls and on the veins they are longitudinally elongated. Stomata are numerous. The *bladders* are like those of the outer epiderm but are less numerous and varied.

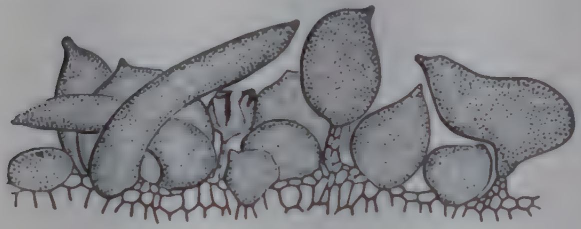

FIG. 62.

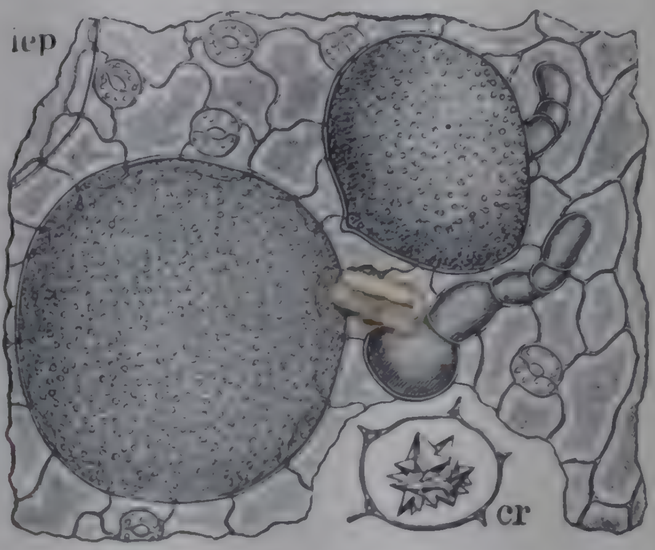

FIG. 63.

FIG. 62.—New Zealand Spinach. Leaf in cross section through lower epiderm over vein showing bladders. × 25. (K.B.W.)

FIG. 63.—New Zealand Spinach. Leaf in surface view. *iep* lower epiderm with one large sunken and two stalked bladders; *cr* crystal cell of mesophyl. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaf halberd-shaped, glistening. Flower small, yellow-green.

Bladders on both surfaces of leaves, also on stem, flower, and young fruit. Outer epiderm with wavy-walled cells; inner epiderm with straight-walled cells. Chlorophyl grains and oxalate rosettes in mesophyl and stem.

CHEMICAL COMPOSITION.—No proximate analysis available.

Acids.—By Bau's method, Ryder[1] found in a single sample 1.20 per cent of *oxalic acid*, doubtless combined as calcium oxalate.

Minor Mineral Constituents. *Iron.*—Edible part 33 to 56 mg. per kilo, fresh basis (Lichtin).[2]

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[1] J. Home Econ. 1930, **22**, 309.

[2] Am. J. Pharm. 1924, **96**, 361.

LEAVES AND STEMS OF THE PURSLANE FAMILY

(*Portulacaceæ*)

Several species of succulent plants belonging to this family yield excellent pot herbs.

PURSLANE

Portulaca oleracea L.

Fr. Pourpier. Sp. Verdolaga. It. Porcellana. Ger. Portulak.

Although best known as a weed, especially troublesome because of its resistance to drought and its numerous minute seeds, purslane or pusley, both wild and cultivated, has value as a pot herb.

MACROSCOPIC STRUCTURE.—The garden weed is prostrate with round, fleshy, green or dull red *stems* and fleshy, spatulate, obscurely nerved, alternate *leaves*, slightly notched at the end. Cooked as a vegetable it is mucilaginous.

MICROSCOPIC STRUCTURE. Stem.—Cross sections show (1) *epiderm* of isodiametric, or longitudinally elongated cells containing the red coloring matter in solution, (2) *collenchyma* several cells thick, (3) *cortex parenchyma* with large cells containing here and there an oxalate rosette, (4) *starch sheath*, (5) *fibro-vascular bundles* with narrow spiral and annular vessels, and (6) *pith* of parenchyma and crystal cells as in cortex.

Leaf.—Both *epiderms* consist of large, wavy-walled cells (elongated over veins) and stomata with large guard cells. Large palisade cells form a distinct row on the inner (upper) side, and commonly a circle of two rows of smaller cells, rich in chlorophyl, surrounds each vascular bundle.

Chief Structural Characters.—Plant smooth and fleshy throughout. Stem round; leaves spatulate, notched.

Stem with oxalate rosettes in cortex and pith; leaves with epiderms of large wavy-walled cells and stomata; palisade cells beneath the upper epiderm.

CHEMICAL COMPOSITION.—Analyses by Storer and Lewis[1] and by Huston[2] follow:

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[1] Bul. Bussey Inst. 1877, **2**, II, 115.

[2] Indiana Agr. Exp. Sta. Rep. 1897, p. 16.

COMPOSITION OF PURSLANE

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
S. and L.	92.61	2.24	0.40	2.16	1.03	1.56
Huston	86.56	1.81	0.50	6.49	2.12	2.23

LEAVES AND STEMS OF THE MUSTARD FAMILY

(*Cruciferæ*)

This family furnishes edible roots, stems, leaves, flowers, and seeds, although the same variety or species may not yield all five. Cauliflower is described under flower vegetables. Such members of the group as form compact heads naturally have blanched inner leaves which thereby gain in tenderness but lose whatever of value may be inherent in the pigments.

COMPARATIVE MACROSCOPIC STRUCTURE.—Kohlrabi is morphologically a stem. Water cress, peppergrass, and mustard greens have more or less lobed or dissected deep green leaves with small divisions. Kale and collards also have green leaves but they are larger and in the latter case are well rounded with little tendency to lobing. Cabbage and Chinese cabbage are characterized by their large, practically entire, leaves forming well-bleached heads, and brussels sprouts by the numerous, small axillary heads suggesting diminutive cabbages. The leaves of cabbage and brussels sprouts are more or less round, of Chinese cabbage spatulate. Kale, collards, and the outer leaves of cabbage have a distinct " bloom " (wax) which is lacking or not evident on Chinese cabbage and the inner leaves of a cabbage head. The short petioles and main ribs of cabbage and cauliflower are thick and fleshy, even at the base, while those of Chinese cabbage, although crisp and succulent, are much thinner, especially at the base.

COMPARATIVE MICROSCOPIC STRUCTURE.—Association of histological characters with characteristic chemical constituents is not noticeable in this group. The location of the minute amount of volatile oil is uncertain. Kohlrabi, although an enlarged stem, has root characters.

Epiderm.—Cells with strongly wavy walls occur in water cress and the outer epiderm of peppergrass; in the other leafy species the walls of the cells between the veins are merely curved or slightly wavy. In kohlrabi the cells are polygonal, tending toward quadrilateral. In cabbage and peppergrass *stomata*, often in pairs, and several subsidiary cells form groups; in kale, collards, and mustard greens the subsidiary cells are larger and often variously elongated; in brussels sprouts only one stoma is usually present in each group; in water cress grouping is not marked but strongly sinuous cells are striking. Distinctly beaded (porous) walls characterize the cell walls of the epiderms of kohlrabi, kale, collards, and mustard greens but not usually of cabbage, brussels sprouts, Chinese cabbage, water cress, and peppergrass. *Hairs* are absent or inconspicuous on cabbage and brussels sprouts. Those on the nerves and ribs of kale, collards, mustard greens, and Chinese cabbage are broadly conical, thin-walled, unicellular, and warty, arising in the case of Chinese cabbage from marked elevations. Striations on the hairs are marked in mustard greens. Large, swollen (non-warty) hairs and bladders are characteristic of water cress; narrow, much-elongated, warty hairs are numerous on peppergrass.

COMPARATIVE CHEMICAL COMPOSITION.—The meager data do not warrant generalization.

PEPPERGRASS

Lepidium sativum L.

Fr. Cresson alénois. Sp. Lepidio. It. Agretto. Ger. Gartenkresse.

The plant, a native of western Asia, has an agreeable spicy flavor and serves for garnishing.

MACROSCOPIC STRUCTURE.—As a result of cultivation the leaves differ widely in the degree of lobing and subdivision. The *stem leaves* vary from entire to pinnately lobed and toothed; the *root leaves* are commonly divided. An Australian variety has golden yellow foliage.

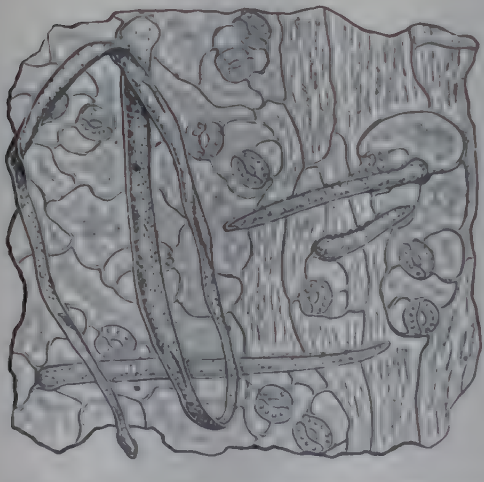

FIG. 64.—Peppergrass. Upper epiderm of leaf in surface view showing warty hairs and transition from elongated cells with striated cuticle over vein to wavy-walled cells between veins. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE.

Petiole.—The *epiderm* consists of greatly elongated, striated cells, also groups of stomata, small subsidiary cells, and hairs.

Leaf Blade.—The *lower epiderm* is free from hairs. The cells between the veins are isodiametric, with strongly wavy walls, and those over the midrib and veins elongated with straight walls. Stomata, often with thickenings at the poles of the guard cells, and subsidiary cells form groups. The cuticle is striated. The *mesophyl* consists of rounded chlorophyl cells among which ramify fibro-vascular bundles with vessels mostly of the spiral, occasionally of the pitted, type. Characteristic of the *upper* (*inner*) *epiderm* (Fig. 64) are the long, strap-shaped (up to 0.5 mm.), and short, pointed hairs. Both forms are thin-walled, unicellular, narrow, and warty. They occur chiefly along the veins and at the tips, being especially noticeable on old leaves. The cells between the veins have less wavy walls than those of the outer epiderm, and the cuticle is not so strongly striate. Thickenings at the poles of the guard cells of the stomata are rare.

Chief Structural Characters.—Leaves entire or variously lobed, toothed, and curled.

Epiderm of petiole and leaves striate with groups of subsidiary cells and stomata; cells on veins and midrib of leaf and on petiole straight-walled and elongated; those between veins of leaf wavy-walled; hairs thin-walled, narrow, warty, long (up to 0.5 mm.) or short.

CHEMICAL COMPOSITION. Minor Mineral Constituents.—Plant 1.5 mg. per kilo, fresh basis (Guérithault).[1]

KOHLRABI

Brassica oleracea L. var. *Caule-Rapa* DC.

Fr. Chou rave. Sp. Nabicol. Ger. Kohlrabi.

Kohlrabi is unique among vegetables in that the stem has a nearly spherical enlargement resembling a white turnip but more delicate in flavor.

MACROSCOPIC STRUCTURE.—Obviously the enlargement is part of the stem since, like a cabbage stalk, it bears leaves on its green or purple glossy surface and it narrows below into a typical stem. The petioles broaden abruptly at the base and after they drop leave narrow, transversely elongated scars. Cross sections show that the thin bundle zone with its cambium layer is near the surface (less than 1 mm.) and that within this is a rather narrow zone of typical pith, but that the inner pith, constituting the bulk of the edible part, contains numerous detached bundles. In the lower part of the enlargement and in the stem below the enlargement, the pith is free from bundles. It thus appears that the thin rind retains the stem characters but the inner thickened part has structural root characters suggesting fleshy roots of the same family.

MICROSCOPIC STRUCTURE.—The layers of tissues are as follows: (1) *epiderm*, covered with a bloom, of small more or less beaded, polygonal cells tending toward quadrilateral, interspersed, especially toward the apex, with stomata; (2) *cortex* of somewhat thickened, porous, polygonal cells, larger than those of the epiderm, with occasional porous, sclerenchyma cells and groups of thick-walled bast fibers, especially in the inner layers; (3) *phloem*; (4) *cambium*; (5) *xylem* with mostly reticulated or pitted vessels and less often spiral vessels; (6) *outer pith* consisting entirely of porous, rounded parenchyma cells passing into (7) *inner pith* differing from the outer in that cobweb groups with or without bundle elements are present.

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[1] Bul. soc. hyg. aliment. 1927, **15**, 386.

The *cobweb groups* are like those of cruciferous roots (see Fig. 17). In their simplest form they consist of small thin-walled cambium-like cells arranged in radiating rows about a common center. Xylem and phloem elements occur in the more robust groups, the vessels, often much distorted, being formed at the edge and the phloem elements at the center. In some the vessels run parallel to the axis of the group; in others they curve about the edge, often forming a complete circle. It is thus evident that the bundles of the inner pith are scattered and are formed independent of the cambium layer, resembling in these respects monocotyledonous bundles. They are not connected with any bundle system of the stem below the enlargement and many of them have blind ends, although at the top of the enlargement some pass into leaf traces.

The *xylem elements* are largely pitted and reticulated vessels, thus showing further agreement with cruciferous roots in structure.

CHIEF STRUCTURAL CHARACTERS.—Stem with globular enlargement; rind thin; outer pith narrow, free from bundles; inner pith thick with detached bundles.

Epiderm of polygonal cells often approaching quadrilateral. Cortex with bast fiber groups. Vessels of bundle ring and inner pith largely reticulated or pitted. Cobweb groups in inner pith.

CHEMICAL COMPOSITION.—The composition of the edible part of 2 samples as compiled by Atwater and Bryant[1] and of 1 sample analyzed by v. Schleinitz[2] follows:

COMPOSITION OF KOHLRABI

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
A. and B.:							
Min.	90.9	1.7	....	0.1	5.4	1.1	1.3
Max.	91.3	2.3	....	0.1	5.6	1.4	1.3
Aver.	**90.1**	**2.0**	**0.5**	**0.1**	**5.5**	**1.3**	**1.3**
v. Schleinitz	92.77	2.02	1.03	0.14	3.57	0.64	0.86

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Landw. Jahrb. 1918, **52**, 131.

Carbohydrates.—Wittmann[1] found 1.37 per cent of *pentosans.*

Minor Mineral Constituents. *Iron.*—Fresh vegetable 6.8 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Copper.—Fresh vegetable 1.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[3]

KALE

Brassica oleracea L. var. *acephala* DC.

Fr. Chou vert. Sp. Breton. It. Cavolo riccio. Ger. Blätterkohl.

The wild species, from which kale and collards, also by further evolution cabbage, brussels sprouts, kohlrabi, and cauliflower, are believed to have sprung, is a native of the rocky coasts of western and southwestern Europe. Cultivation and selection have brought about certain changes in the leaves of kale but no tendency to form a compact head. American seedsmen list two principal types of curled kale, the Scotch and the Siberian. Among the points in favor of kale are its easy cultivation, resistance to frost and even freezing, and good shipping qualities.

MACROSCOPIC STRUCTURE.—As shown by the broadly triangular leaf scars, the smooth *leaves*, each with a bud in its axil, are arranged in a rather close four-rowed spiral. Both petiole and midrib are light green and neither is distinctly ribbed nor very fleshy. On the other hand the reticulations between the main veins are pronounced. The area of the thin, dark green leaf tissue is much reduced by lobing. The outer part of the leaf blade shows indistinct lobing but strong compound curling necessitated by the great expansion at the edges. Toward the base the lobes become more pronounced, forming finally divisions, often mere scales, separated by naked stretches of midrib.

MICROSCOPIC STRUCTURE. Petiole.—Both petiole and midrib of leaf into which it runs have practically the same structure. The tissues, starting with the lower surface, consist of (1) *lower* (*outer*) *epiderm* of elongated, straight-walled cells and an occasional stoma but no hairs; (2) *collenchyma*, a number of cells thick; (3) *ground tissue* of rounded cells, sometimes containing transitory starch grains up to 10 μ in diameter, through which run the fibro-vascular bundles with spiral, reticulated, and pitted vessels; and (4) *upper epiderm* similar to the lower epiderm.

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[1] Z. landw. Versuchsw. Oesterr. 1901, **4**, 131.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Ibid. 1929, **82**, 465.

Leaf Blade.—The walls of the *outer* (*lower*) *epiderm* (Fig. 65) are thin but distinctly beaded. Over the veins stomata are rare, the outer epidermal tissue consisting chiefly of elongated, straight-walled cells, and occasional stiff, unicellular, pointed hairs, the thick walls of which bear numerous elongated warts. Between the veins the tissue consists of groups of one or more stomata and small subsidiary cells, the groups being separated by irregularly elongated cells. Except on the guard cells of the stomata, the cuticle is covered with a waxy bloom appearing as small dots. Through the chlorophyl parenchyma of the *mesophyl* ramify the *fibro-vascular bundles* of the veins consisting of spiral, reticulated, and pitted vessels.

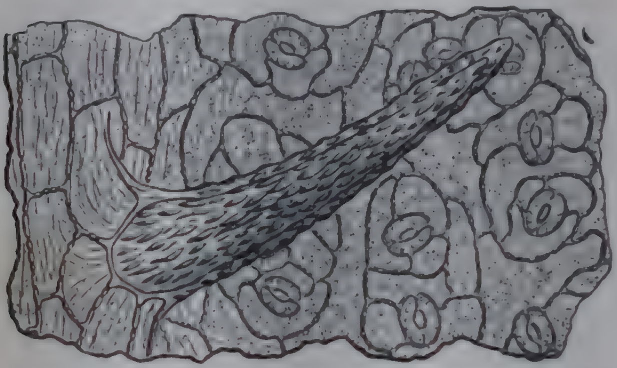

Fig. 65.—Kale. Lower epiderm of leaf in surface view showing transition from straight-walled cells with warty hair over vein to grouping of stomata and subsidiary cells between veins. × 160. (K.B.W.)

The *upper* (*inner*) *epiderm* differs chiefly from the lower in that usually only one stoma occurs in each group.

Chief Structural Characters.—Leaves smooth, lyrate, commonly much curled. Petiole, midrib, and main ribs light green; tissue between veins dark green.

Epiderm beaded; on veins of elongated, straight-walled cells and occasional, unicellular, thick-walled, warty hairs; between the veins of groups of stomata and small subsidiary cells separated by irregularly elongated cells. Inner tissues much as in other members of the group.

CHEMICAL COMPOSITION.—Dahlen[1] analyzed the ribs and leaf parenchyma separately, as shown recalculated below. Chung and Ripperton[2] give a single analysis of a non-curly kale as found on the Hawaiian market where the whole plant, with or without flowers, is offered under the Chinese name *kai-lan-choi*.

Composition of Kale

	Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
	%	%	%	%	%	%	%
Dahlen:							
Ribs (37.6%)	82.30	3.07	0.39	10.86	1.93	2.12	1.26
Parenchyma (62.4%)	79.69	2.77	0.99	13.43	0.72	1.63	1.49
C. and R.:							
Whole plant	91.24	2.82	0.21	2.94	....	1.05	1.74

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[1] Landw. Jahrb. 1874, **3**, 321.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

Carbohydrates.—Wittmann[1] found 2.03 per cent of *pentosans.*

Mineral Constituents.—Chung and Ripperton[2] found: calcium 0.195, iron 0.0035, and phosphorus 0.060 per cent; also alkalinity of ash 17.7 expressed as cubic centimeters of normal acid per 100 grams of fresh vegetable.

COLLARDS

Brassica oleracea L. var. *acephala* DC.

Fr. Chou coba. Sp. Cabu. It. Cavolo comune. Ger. Blätterkohl.

This leaf vegetable, classed by some authorities as a non-curling kale, is grown in the southern states for greens.

MACROSCOPIC STRUCTURE.—The *leaves* resemble those of the cabbage, being well rounded and only slightly lobed. They are covered with a bloom.

MICROSCOPIC STRUCTURE.—Practically the same as that of kale.

CHEMICAL COMPOSITION.—Friedemann and Holley[3] report the following average of 3 analyses:

Water	Protein	Fat	N-f. ext.	Fiber	Ash	Ca .	Fe	P
%	%	%	%	%	%	%	%	%
87.68	3.91	0.36	5.40	1.01	1.64	0.2070	0.0039	0.0750

CABBAGE

Brassica oleracea L. var. *capitata* L.

Fr. Chou pommé. Sp. Col repello. It. Cavolo capuccio.
Ger. Kopfkohl.

Of all leaf vegetables cabbage is perhaps the most valuable. It was developed in prehistoric times from the same wild plant as kale but is further removed from the parent form.

Sauerkraut, prepared by the lactic fermentation of cabbage mixed with salt, and various kinds of pickles are common commercial products.

MACROSCOPIC STRUCTURE.—Aside from forming a head with inner leaves blanched by exclusion of light, cabbage differs from kale in having well-rounded leaves. All varieties have fleshy stalk, petioles, midribs, and main veins. Classed according to the shape of the *head*, there are round, oval, pointed, and oblate varieties. The *petioles* and lower *midrib* have five indistinct ridges on the outer side which disappear on the midrib where the bundles beneath them pass into the main veins. The scars left on the stalk after the dropping of the lower leaves show clearly the five main bundles. The veins forming the meshes between the main veins are not prominent except in Savoy varieties. The commonest varieties have blue-green, glaucous *leaf blades* free from marked irregularities; Savoy cabbage, however, is characterized by the blistered appearance of the inner surface, due to the bending inward of the leaf tissue between the reticulations. A bloom is evident on the older leaves but not on the inner leaves of the compact head where it would be of less use in preventing evaporation.

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[1] Z. landw. Versuchsw. Oesterr. 1901, **4**, 131.

[2] Loc. cit.

[3] Georgia Exp. Sta. 1928, Press Bul. **278**.

Red cabbage is remarkable in that the midribs and main veins throughout are red or purple, whereas the tissues in the meshes of leaves exposed to the light are blue-green with a reddish tint and glaucous but in the inner part of the compact head they are red. It thus is evident that although exclusion of light prevents the formation of chlorophyl it does not affect the red coloring matter. The color of the slightly acid juice is red, becoming on addition of alkali green, a color reaction employed by early chemists in titration.

MICROSCOPIC STRUCTURE.—In general structure, cabbage corresponds with kale, the points of difference being, in part at least, due to the formation of the compact head in the former and the spreading habit of the leaves in the latter. *Hairs*, which occur on the veins of kale, are not found on the edible leaves of cabbage. The cell walls of the *epiderm* of kale are distinctly beaded while those of the edible leaves of cabbage are not. The outer epiderm of cabbage, as shown in Fig. 66, has more and smaller subsidiary cells in the groups with the stomata than that of kale, but this distinction is largely due to the immaturity of the leaves from a compact head as compared with those of kale. The internal structure of the leaves of both varieties appears to be identical.

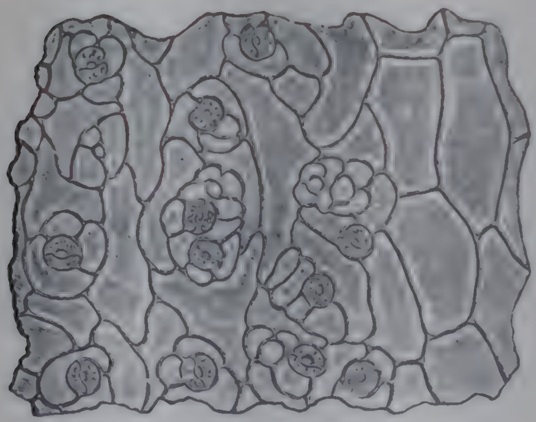

FIG. 66.—Cabbage. Lower epiderm of leaf in surface view showing transition from straight-walled cells over vein to groups of stomata and subsidiary cells separated by elongated cells between veins. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaves in compact heads with little or no chlorophyl. Petiole and midrib more fleshy than in kale.

Epiderms of leaves constituting the inner part of the head without beads, bloom, or hairs; two stomata often in groups with more and smaller subsidiary cells than in kale. Structure otherwise practically the same as that of kale.

CHEMICAL COMPOSITION.—As given in the table below, analyses of the whole head made by Richardson[1] at different stages of development show, in the water-free material, no striking differences in composition after the early stages. Compared with these analyses of the whole head, analysis of the interior blanched portion, collected two months later, shows less ash and fiber but more protein and nitrogen-free extract. The minimum protein content, shown in Atwater and Bryant's Compilation,[2] seems unreasonably low, even if associated with the maximum water content. Analyses by v. Schleinitz[3] of cabbage of different colored varieties do not warrant any sweeping con-

COMPOSITION OF CABBAGE

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Richardson:							
Whole head							
June 2	88.39	2.71	....	0.67	3.86	0.94	3.43
June 26 (466 grams)	87.39	2.94	....	0.69	5.11	1.32	2.55
July 3 (549 grams)	86.01	2.62	....	0.74	6.38	1.55	2.70
July 10 (925 grams)	87.46	2.72	....	0.54	5.69	1.51	2.08
Interior							
Oct. 15 (436 grams)	94.31	1.48	....	0.24	2.87	0.54	0.56
A. and B. (16 samples):							
Edible part (85%)							
Min.	86.0	0.2	....	0.1	3.4*	0.5	0.4
Max.	94.3	2.9	....	0.7	8.0*	1.6	2.4
Aver.	**91.5**	**1.6**	....	**0.3**	**5.6***	**1.1†**	1.0
v. Schleinitz:							
White	94.11	1.20	0.65	0.13	3.29	0.69	0.58
Red	93.10	1.50	0.88	0.15	3.79	0.80	0.66
Rose	83.62	5.75	3.16	0.47	7.10	1.33	1.73
Green	80.97	5.80	3.39	0.88	8.95	1.85	1.55
Savoy	92.11	2.01	1.23	0.18	4.03	0.82	0.75
Agcaoili	91.86	2.08	....	0.28	4.13	0.91	0.79

* Includes fiber. † 8 samples.

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[1] U. S. Dept. Agr. Rep. 1883, p. 240.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[3] Landw. Jahrb. 1918, **52**, 131.

clusions as to the varieties, even when reduced to the same water content. The analysis by Agcaoili[1] is of cabbage grown in the Philippines.

Changes in Composition During Storage.—Weiser and Kurelec[2] found no marked variation during the Winter months.

Proteins.—*The Nitrogen Distribution*, as determined by Yoshimura[3] in fresh cabbage leaves containing 89.4 per cent of water and 0.311 per cent of nitrogen, follows: protein nitrogen 0.091, ammonia nitrogen trace, and non-protein nitrogen (including phosphotungstic precipitate 0.051 and other forms 0.169) 0.220 per cent.

Peterson, Fred, and Viljoen[4] note variations as follows: total nitrogen 0.15 to 0.24 and soluble nitrogen 0.06 to 0.16 per cent.

Nitrogenous Bases.—In 50 kilos of the fresh material Yoshimura[3] found: *histidine* present, *arginine* 0.7 gram, *lysine* 0.2 gram, *choline* 0.3 gram, and *betaine* 0.1 gram.

Of interest in this connection is *erepsin* extracted by Blood[5] from white cabbage. This enzyme splits off tryptophane from Witte's peptone and casein, also tyrosine from Roche's peptone.

Fat. *Physical and Chemical Values.*—Ozaki[6] obtained, by ether extraction and elimination of substances insoluble in petroleum ether and acetone, a dark-colored oil with the following values: saponification number 144.1, iodine number 103.4, Reichert-Meissl number 2.0, Hehner number 61.6, acid number 21.2, and unsaponifiable matter 21.7 per cent.

Composition.—According to Ozaki[6] the saturated acids, constituting 16.3 per cent of the total acids, contained: arachidic 10 and palmitic at least 80 per cent together with a small amount of myristic but no stearic; the unsaturated acids contained linolenic 10, an isomer of linolic 75, and an isomer of oleic at least 10 per cent.

The same author[7] saponified the ether extract of the blanched leaves of cabbage, extracted with ether, and agitated with water. A waxy substance separated, forming a layer between the aqueous and ether solutions, which, dissolved in acetone, yielded crystals corresponding to *palmitone*, melting at 81 to 82° C., and in the mother liquor *n-hentriacontane*, melting at 68° C. The author concluded that palmitone is condensed from palmitic acid, *n*-hentriacontane being formed from palmitone by reduction.

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[1] Philippine J. Sci. 1916, **11**, 91.

[2] Wiss. Arch. Landw. Abt. B, Tiernähr. Tierzucht 1930, **2**, 422.

[3] Z. Unters. Nahr-Genussm. 1910, **19**, 253.

[4] Canner 1925, **61**, 19.

[5] J. Biol. Chem. 1910, **8**, 215.

[6] J. Agr. Chem. Soc. Japan 1930, **6**, 688.

[7] Ibid. 1930, **6**, 773.

The ether extract was prepared by Chibnall and Channon[1] by expressing the juice of the leaves, freed from thick midribs, coagulating at 70° C., cooling, filtering, removing the excess liquid by pressure, drying the coagulum, and extracting with ether. The following amounts of the constituents, expressed as percentages of the extract, are given in the final paper of the series: chlorophyl (α and β) 9.3, carotene 0.5, xanthophyl 0.8, calcium phosphatidate 18.5, unidentified calcium salts 5.1, unidentified iron compound 3.0, glycerides and waxes (containing palmitic, stearic, linolic, and linolenic acids) 17.4, glycerol 1.3, unsaponifiable matter (chiefly *n-nonacosane*, $C_{29}H_{60}$) and *di-n-tetradecyl ketone*, $C_{14}H_{29}\cdot CO\cdot C_{14}H_{29}$) 12.3, sterols by digestion 4.4, and unidentified (probably alcohol and hydrocarbons) 13.3, total 85.9 per cent.

Carbohydrates.—Sugar, according to Peterson, Fred, and Viljoen,[2] varies from 3 to 4.2 per cent in fresh cabbage.

Olmsted[3] estimated the available carbohydrates, by taka-diastase and by feeding phlorhizinized dogs, to be as follows: raw cabbage 4.4 and 5.0 per cent and thrice-cooked cabbage 0.4 and 0.5 per cent.

A new crystalline carbohydrate with the probable formula $CH_2(OH)\cdot CH(OH)\cdot O\cdot CH_2OH$ has been isolated by Buston and Schryver[4] from a water extract of minced cabbage leaves, after previous removal of chlorophyl and fat by ether, proteins by Chibnall and Schryver's method, and other nitrogenous substances by precipitation with phosphotungstic acid and baryta-alcohol. This substance may form a stage in the making of a pyrone ring which is an important molecular constituent of the anthocyanins.

Phosphorus-Organic Compounds.—Chibnall and Channon (see Fat above) state that all the so-called phospholipin fractions obtained by adding acetone to the ether solution of the fat, contain no true phospholipins, all the phosphorus being combined as the calcium salt of diglyceride phosphoric acid of the type $RO_2CCH_2CH(O_2CR')CH_2OPO_3H_2$. The acid, to which the authors assign the name phosphatidic acid, is the parent substance of lecithin and cephalin.

Phytin.—Bagaoisan[5] reports 4.11 per cent, dry basis.

Colors.—From ordinary cabbage Ozaki[6] isolated *carotene* and *xanthophyl.* From red cabbage Willstaedt[7] obtained blue-black crystals of a substance containing a higher percentage of carbon (63.58) than in anthocyanins; Chmielewska,[1] however, isolated an anthocyanin pigment as the chloride ($C_{28}H_{33}O_{16}Cl$), apparently isomeric with peonin, with one equivalent of peonidin (monomethyl cyanidin) and two of dextrose.

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[1] Biochem. J. 1927, **21**, 225, 233, 479, 1112; 1929, **23**, 168, 176.

[2] Loc. cit.

[3] J. Biol. Chem. 1920, **41**, 45.

[4] Biochem. J. 1923, **17**, 470.

[5] Philippine Agr. 1932, **21**, 53.

[6] Loc. cit.

[7] Biochem. Z. 1931, **242**, 303.

Enzymes.—See *erepsin* under Nitrogenous Bases.

Mineral Constituents.—Ash analyses appear in the compilations of Atwater and Bryant[2] and Haskins[3] as follows:

	K_2O	Na_2O	CaO	MgO	P_2O_5
	%	%	%	%	%
Atwater and Bryant:					
In cabbage ash	61.50	6.30	4.70	1.90	5.50
Haskins:					
In fresh white cabbage	0.34	0.03	0.02	0.01	0.02

Ripperton and Russell[4] have analyzed cabbages grown on the mainland and in Hawaii from the same seed with the following results in terms of percentages of dry matter:

	K	Ca	Mg	Fe	Mn	P	S	Cl	Alkalinity*
	%	%	%	%	%	%	%	%	%
Mainland	4.38	0.78	0.30	0.014	0.0025	0.46	0.53	0.26	118.8
Hawaii	3.95	0.67	0.35	0.009	0.0018	0.45	0.62	0.63	102.8

* Cc. *N* acid per 100 grams.

Peterson and Peterson[5] give a summary of results on 18 samples grown in 1924 and 12 grown in 1925, on the fresh basis, as follows:

	Water			Calcium			Phosphorus		
	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
	%	%	%	%	%	%	%	%	%
1924	91.0	93.9	**92.6**	0.029	0.056	**0.043**	0.017	0.037	**0.024**
1925	92.9	93.9	**93.4**	0.038	0.053	**0.046**	0.023	0.036	**0.028**

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[1] Roczniki Chem. 1933, **13**, 725.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[3] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[4] Hawaii Agr. Exp. Sta. 1926, Bul. **9**.

[5] J. Agr. Res. 1926, **33**, 695.

Minor Mineral Constituents. *Iron.*—Edible portion 9 mg. per kilo, fresh basis (Sherman)[1] Inner leaves, 4 outer leaves 14 mg. per kilo, fresh basis (Häusermann quoted by Sherman).[1] Head 3.4 mg. per kilo, fresh basis (Peterson and Elvehjem).[2] Edible portion, 8 samples, 74 to 305, aver. **132** mg. per kilo, dry basis (Remington and Shiver).[3] Head, 2 samples, 3.8, 6.4 mg. per kilo, fresh basis (Toscani and Reznikoff).[4]

Aluminum.—Outer green leaves 232, interior 0.8 mg. per kilo, dry basis (Bertrand and Lévy).[5]

Manganese.—Edible portion, 7 samples, 30.7 to 47.7, aver. **40.7** mg. per kilo, dry basis (Remington and Shiver).[3]

Copper.—Edible portion, 8 samples, 4.5 to 8.0, aver. **6.3** mg. per kilo, dry basis (Remington and Shiver).[3] White head 1.8 mg. per kilo, fresh basis (Guérithault).[6] Head 0.5 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

Zinc.—White head 1.6 mg. per kilo, fresh basis (Bertrand and Benzon).[8] Edible part 12.9 to 17.8 mg. per kilo, dry basis (Hubbell and Mendel).[9]

Composition of Sauerkraut.—The changes that take place during fermentation, as shown by Peterson, Fred, and Viljoen,[10] affect chiefly the soluble nitrogen and carbohydrates. In 7 samples they found the following range:

COMPOSITION OF SAUERKRAUT (PETERSON, FRED, AND VILJOEN)

	Water	Fixed acids as lactic	Volatile acids as acetic	Sugars
	%	%	%	%
Min......	89.6	1.13	0.28	0.09
Max......	91.5	1.52	0.42	0.77

The drained kraut and the juice contain nearly the same percentages of soluble constituents. The content of total and soluble nitrogen in both cabbage and kraut differs little, but of amino nitrogen in the kraut is about 50 per cent higher than in the cabbage.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.
[2] J. Biol. Chem. 1928, **78**, 215.
[3] J. Ass. Off. Agr. Chem. 1930, **13**, 129.
[4] J. Nutrition 1934, **7**, 79.
[5] Bul. soc. hyg. aliment. 1931, **19**, 359:
[6] Ibid. 1927, **15**, 386.
[7] J. Biol. Chem. 1929, **82**, 465.
[8] Bul. soc. hyg. aliment. 1928, **16**, 457.
[9] J. Biol. Chem. 1927, **75**, 567.
[10] Loc. cit.

BRUSSELS SPROUTS

Brassica oleracea L. var. *gemmifera* DC.

Fr. Chou de Bruxelles. Sp. Bretones de Bruselas. It. Cavolo a germoglio. Ger. Rosenkohl.

Like cauliflower, this vegetable is an aristocratic member of the cabbage family, remarkable for its delicate flavor.

MACROSCOPIC STRUCTURE.—The *heads* are morphologically diminutive cabbages, formed from the buds in the leaf axils.

MICROSCOPIC STRUCTURE.—The microscopic structure is much like that of cabbage, the only marked difference noted being that more than one *stoma* in a group is seldom if ever present. The elongated cells accompanying the *fibro-vascular bundles* of the stem often have somewhat thickened, porous walls.

CHIEF STRUCTURAL CHARACTERS.—Heads diminutive, otherwise as in cabbage.

Only one stoma usually present in a group.

CHEMICAL COMPOSITION.—McElroy and Bigelow,[1] in a sample of brussels sprouts canned at Bordeaux, found:

Water	Protein	Fat	N-f. ext.	Fiber	Ash, total	Ash, salt-free	Salt
%	%	%	%	%	%	%	%
93.75	1.49	0.07	2.86	0.56	1.27	0.34	0.93

The sample contained 63.7 mg. per kilo of copper added for coloring.

Fat.—In the leaf wax Sahai and Chibnall[2] identified *n*-nonacosane, 15-nonacosanone, 15-nonacosanol, ceryl alcohol, cerotic acid, and probably *n*-hentriacontane, all believed to be end products of metabolism, but no olefins.

Minor Mineral Constituents. *Iron.*—Head 22.3 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Copper.—Head 1.0 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

---

[1] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, 1131.

[2] Biochem. J. 1932, **26**, 403.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Ibid. 1929, **82**, 465.

TURNIP GREENS

Young plants of both turnip and rutabaga, often obtained by thinning, make excellent greens.

CHEMICAL COMPOSITION.—The average composition of 4 samples, analyzed by Friedemann and Holley,[1] follows:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
88.01	3.42	0.29	5.41	1.07	1.80

Mineral Constituents.—The above-named authors found: calcium 0.2160, iron 0.0095, and phosphorus 0.0747 per cent, calculated to the fresh material.

Minor Mineral Constituents. *Zinc.*—Leaf 2.1 mg. per kilo, fresh basis (Bertrand and Benzon).[2]

POT-HERB MUSTARD

Brassica japonica Thunb.

Jap. Mizu-na. Chin. Sui-choi.

Kondo[3] states that this vegetable is much grown in Japan. He describes the seeds and seedlings of two varieties, *mibu-na* and *sensuzi-kiō-na*, both known under the general name of *mizu-na*. Chung and Ripperton[4] give *midsuna* as the Japanese name and *Sinapis chinensis* as the Latin name. They state that in Hawaii it is used by the Japanese exclusively at the seedling stage. The plant has long been grown in the United States for greens.

MACROSCOPIC STRUCTURE.—Chung and Ripperton[4] state that the *leaves* are distinguished from those of Chinese mustard by their deep lobes and sharp-toothed margins; further that the *petioles* are slender, white, and smooth, the upper surface being flat and the lower surface rounded.

MICROSCOPIC STRUCTURE.—The histological structure differs from that of kale in that (1) the *cell walls* are commonly thicker and more distinctly beaded and (2) the *hairs* which occur sparingly on the main veins are striated as well as warty and so strongly thickened that the end for some distance consists entirely of wall. As regards the stomata groups there is no marked distinction.

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[1] Georgia Exp. Sta. 1928, Press Bul. **278**.

[2] Bul. soc. hyg. aliment. 1928, **16**, 457.

[3] Ber. Ohara Inst. landw. Forsch. 1917, **1**, 139.

[4] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

CHEMICAL COMPOSITION.—In the table below, the average of 3 analyses by Friedemann and Holley[1] is of mustard greens, grown in Georgia, presumably from *B. japonica.* The analysis by Chung and Ripperton[2] is of greens of that species grown in Hawaii.

COMPOSITION OF POT-HERB MUSTARD

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Ca	Fe	P
	%	%	%	%	%	%	%	%	%
F. and H. .	86.66	4.27	0.21	5.57	1.26	2.03	0.291	0.0093	0.084
C. and R. .	95.24	1.53	0.06	1.51	0.65	1.01	0.070	0.0031	0.038

CHINESE CABBAGE

Brassica pe-tsai Bailey

Chin. Wong-nga-bak. Jap. Shanto-na.

Bailey[3] assigns to the above species the varieties of Chinese or celery cabbage forming close heads, cataloged by American seedsmen under the names of *wong bok* and *pe tsai.* The Chinese and Japanese names given in the heading are on the authority of Chung and Ripperton.[4] *pak choi* (*B. chinensis* L.), also called Chinese cabbage, never forms a head. As a Fall salad vegetable, *wong bok* is of exceptional excellence, rivaling ordinary cabbage and endive.

MACROSCOPIC STRUCTURE.—The *heads* differ from common cabbage in being club-shaped, often twice as long as broad. The *leaves* are spatulate, nearly or quite sessile, and inconspicuously lobed but with broadly crisped margins. At the base the *midrib* is much thinner but broader than that of cabbage and shows seven to nine distinct corrugations becoming successively secondary ribs. Both the breadth and the number of ribs decrease more abruptly than in cabbage. Stiff, transparent hairs, up to 1 mm. long, occur on both sides, being especially abundant on the veins of the outer side and on the edge.

[1] Georgia Exp. Sta. 1928, Press Bul. **278**.

[2] Loc. cit.

[3] Cornell Agr. Exp. Sta. 1904, Bul. **67**.

[4] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

The leaves outside of the head are bright green and non-glaucous with nearly pure white ribs and veins.

MICROSCOPIC STRUCTURE.—As in the varieties of *Brassica oleracea*, the cells of both *epiderms* over the veins (Fig. 67, ep^2) are mostly elongated and straight-walled while between the veins (ep^1) they are small subsidiary cells, grouped with the stomata, or irregularly elongated, separating the groups. The *hairs* (*t*) arise from slight elevations. They are broad at the base, tapering to the apex. On the surface are numerous elongated warts. The *mesophyl* is characterless. As is true of the cabbage group, the vessels of the *fibro-vascular bundles* are largely spiral.

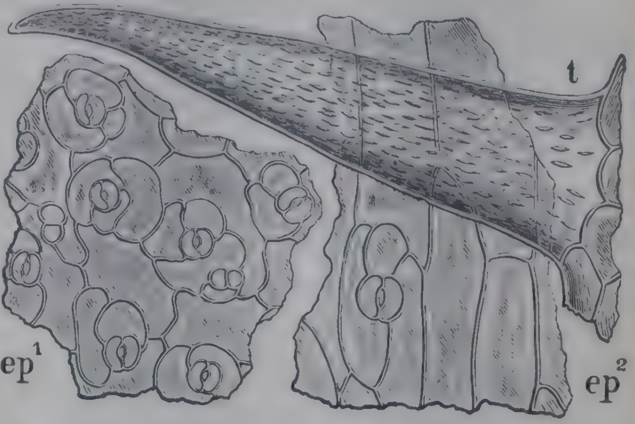

FIG. 67.—Chinese Cabbage. Lower epiderm in surface view. ep^1 between veins; ep^2 over midrib; *t* hair over vein. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaves spatulate with crisped edge; midrib broader but much thinner at the base than in cabbage. Hairs, up to more than 1 mm. long, present on veins.

Epiderms over the veins with elongated, straight-walled cells, between the veins with groups of subsidiary cells and stomata; hairs conical, broad at base, with elongated warts, on elevations.

CHEMICAL COMPOSITION.—Three analyses are given below, one by Blasdale[1] of a sample grown by the Chinese in California and known there as *pe-tsai*, one by Adolph[2] of a sample collected as *pai-tsai* and analyzed in China, and one by Chung and Ripperton[3] of a sample grown in Hawaii and known there by the names given above:

COMPOSITION OF CHINESE CABBAGE

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Ca	Fe	P
	%	%	%	%	%	%	%	%	%
Blasdale...	95.74	1.19	0.15	1.84*	0.52	0.56	......	......	......
Adolph....	95.42	1.21	0.06	1.99	0.76	0.56	......	......	......
C. and R..	96.04	1.58	0.05	1.61	0.50	0.66	0.037	0.0008	0.057

* Reducing sugars 1.29, sucrose 0.09, starch 0.31%.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Philippine J. Sci. 1926, 30, 287.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. 60.

Proteins.—As determined by Kao,[1] the nitrogen in parts of the plant ranges as follows on the dry basis: blade 4.6 to 6.1, stalk 2.53 to 4.08, and root and stem 3.3 to 5.5 per cent.

Minor Mineral Constituents. *Iron.*—Celery cabbage 5.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Manganese.—Celery cabbage 23.3 mg. per kilo, dry basis (Peterson and Skinner).[3]

Copper.—Celery cabbage 0.6 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

WHITE MUSTARD CABBAGE

Brassica chinensis L.

Jap. Shirona. Chin. Bak-choi; Pak-choi.

Chung and Ripperton[5] state that four forms of this vegetable are found on the Hawaiian market: (1) *bak-choi-sum* with slender round petioles and narrow leaves and a profusion of yellow flowers, (2) the *shakushina*, a Japanese variety, with long slender petioles and oval leaves, (3) a stout and fleshy variety without flowers, and (4) *bak-choi-chai*, the seedling plants of the three foregoing varieties obtained in thinning.

MACROSCOPIC STRUCTURE.—Chung and Ripperton give the following details: *head* loose; *petiole* smooth, white, fleshy, and glossy; *leaf* short, green, broadly obovate, entire, firm, glossy, and scallop-edged.

MICROSCOPIC STRUCTURE.—No data.

CHEMICAL COMPOSITION.—Analyses by Blasdale[6] and by Chung and Ripperton[7] appear below:

Composition of White Mustard Cabbage

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Ca	Fe	P
	%	%	%	%	%	%	%	%	%
Blasdale	96.55	0.78	0.10	1.16*	0.46	0.65	......	......	......
C. and R.:									
Flowering	93.68	2.07	0.14	1.94	0.85	1.31	0.109	0.0031	0.062
Japanese	95.62	1.55	0.06	1.21	0.46	1.10	0.121	0.0018	0.037
Stout	95.12	1.37	0.08	1.72	0.47	1.24	0.096	0.0022	0.025

* Reducing sugars 0.37, sucrose 0.09, starch 0.31%.

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[1] Chinese J. Physiol. 1933, **7**, 379.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] J. Nutrition 1931, **4**, 419.

[4] J. Biol. Chem. 1929, **82**, 465.

[5] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[6] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[7] Loc. cit.

CHINESE MUSTARD

Brassica juncea Coss = *Sinapis chinensis* L. = *B. ramosa* Roxb.

Jap. Taka-na. Chin. Kai-choi.

Kondo[1] gives, in addition to the above, two other Japanese names, *o-garaschi* and *kaki-na.* He states that the rank-growing plant is much grown in Japan, and the large, somewhat spicy leaves are used as a vegetable. Chung and Ripperton[2] state that under the name of " leaf-mustard cabbage " or " green mustard " both the seedlings and partly developed plants are sold in Hawaiian markets. In the Philippines, according to Agcaoili,[3] the vegetable is known as *mustaza.*

MACROSCOPIC STRUCTURE.—The *plant* reaches over 1 meter in height; the *leaves* reach 60 cm. in length (Kondo).[1] The *petiole* is swollen, curved or straight, usually with white bloom; the *leaf blade* is oval to broad or oblong to ovate, with a notched margin, and a crepe-like surface (Chung and Ripperton).[2]

MICROSCOPIC STRUCTURE.—No data.

CHEMICAL COMPOSITION.—Analyses by Agcaoili[3] and Chung and Ripperton[2] appear below:

Composition of Chinese Mustard

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Ca	Fe	P
	%	%	%	%	%	%	%	%	%
Agcaoili. . .	91.30	2.06	0.31	4.43	0.80	1.10	. . . .	. . . .	. . . . . .
C. and R. .	94.22	1.99	0.07	1.90	0.65	1.17	0.884	0.0035	0.046

WATER CRESS

Roripa Nasturtium Rusby = *Nasturtium officinale* R. Br.
= *Sisymbrium Nasturtium* L.

Fr. Cresson de fontaine. Sp. Berro. It. Crescione di fontana.
Ger. Brunnenkresse.

Brooks and pools, once stocked with water cress, often become so clogged with the plants as to render extermination or control exceedingly difficult. Originating in the Old World, the plant is now widely distributed. The flavor is agreeably sharp and mustard-like.

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[1] Ber. Ohara Inst. landw. Forsch. 1917, **1**, 142.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[3] Philippine J. Sci. 1916, **11**, 91.

MACROSCOPIC STRUCTURE.—The *leaves* are alternate and pinnately divided, the end leaflet being rounded, often with a heart-shaped base, and the lateral leaflets, which are smaller, ovate or elliptical. The *rootlets* are white and thread-like. They spring from along the stem, even to the tip.

MICROSCOPIC STRUCTURE. Stem.—The *epiderm* consists of greatly elongated, often faintly beaded cells and stomata, the latter being usually one above the other in rows. Many of the cells are bladder-like and in addition much longer and broader than the others. These bladder-like cells also occur on the petioles and leaves, serving to give buoyancy to the plant. The bulk of the tissue is *cortex* consisting of chlorophyl parenchyma. No collenchyma is present. The *fibro-vascular bundles* are arranged about the narrow *pith*.

Petiole.—The *lower* (*outer*) *epiderm* consists of greatly elongated cells (up to 0.5 mm. or more), many distended into bladders, and stomata.

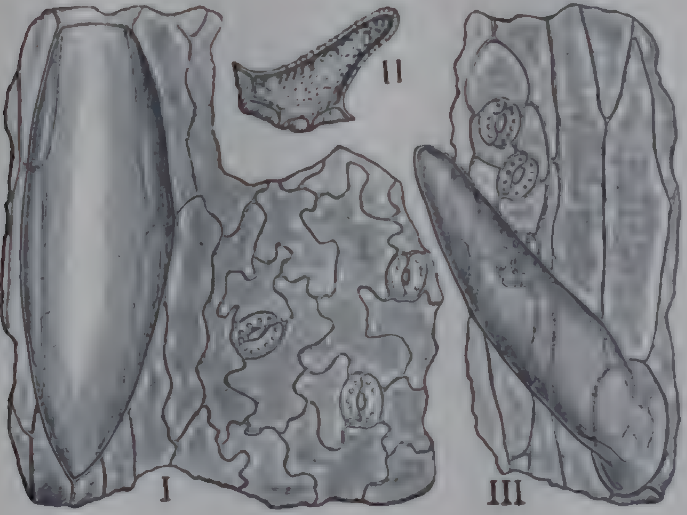

Fig. 68.

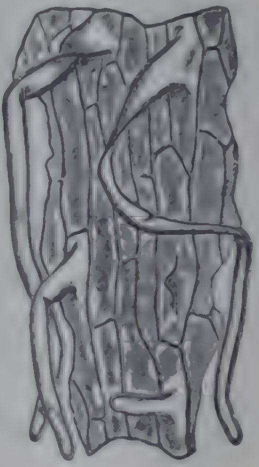

Fig. 69.

Fig. 68.—Water Cress. Elements of leaf in surface view. I lower epiderm of leaf blade showing a bladder cell and straight-walled, elongated cells over vein, also wavy-walled cells and stomata between veins; II hair from edge of leaf at tip; III upper epiderm of petiole showing large hair and group of stomata × 160. (K.B.W.)

Fig. 69.—Water Cress. Epiderm of young rootlet in surface view with root hairs. × 160. (K.B.W.)

Hairs are absent. Similar to the cortex of the stem and the veins of the leaf, the *mesophyl* consists of chlorphyl parenchyma in which are the *fibro-vascular bundles*. Both spiral and reticulated vessels are present. The *upper* (*inner*) *epiderm* (Fig. 68, III) differs from the lower in having scattered among the cells transparent unicellular, blunt-pointed *hairs*, up to 0.5 mm. long, which, like the bladder cells, are buoyant.

Leaf Blade.—The midrib and veins have practically the same structure as the petiole. Between the veins the *lower epiderm* (Fig. 68, I) consists of wavy-walled cells with angular turns and stomata, the latter often with horns at the poles of the guard cells. On the edges short, blunt, unicellular *hairs* (Fig. 68, II) with striated cuticle are present. Typical chlorophyl parenchyma and delicate fibro-vascular bundles with vessels mostly of the spiral type make up the *mesophyl.* The *upper epiderm* differs from the lower in having hairs, up to 200 μ, at the tip.

Root.—Fig. 69 shows the elongated *epidermal cells,* many of which are extended as root hairs, varying from short nipple-shaped to elongated, twisted, strap-shaped forms.

CHIEF STRUCTURAL CHARACTERS.—Leaves pinnately divided with rounded leaflets; stem succulent with white rootlets.

Epiderm of stem, lower epiderm of petiole, midribs, and veins composed of elongated cells, often forming bladders; upper epiderm of petiole with bladder-like hairs; edge of leaflet with short, striated hairs; cells between veins deeply wavy-walled. Root with nipple-shaped or long, twisted, strap-shaped root hairs.

CHEMICAL COMPOSITION.—Chung and Ripperton[1] give a single analysis of fresh water cress from the Hawaiian market, and Valenzuela and Wester[2] give one of air-dry material from the Philippines.

COMPOSITION OF WATER CRESS

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
C. and R.	94.86	2.00	0.11	1.28	0.64	1.11
V. and W.	12.28	27.65	3.11	31.80	10.16	15.00

Mineral Constituents.—Chung and Ripperton[1] found: calcium 0.085, iron 0.0022, and phosphorus 0.053 per cent; also alkalinity of ash 11.7 as cubic centimeters of normal acid per 100 grams of fresh vegetable.

Minor Mineral Constituents. *Iron.*—Plant 72.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Manganese.—Plant, 2 samples, 69.1 mg. per kilo, dry basis (Peterson and Skinner).[4]

Copper.—Plant, fresh 1.5, dry basis 18.1 mg. per kilo (Guérithault).[5] Plant 0.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Stem and leaves 5.6 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

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[1] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[2] Philippine J. Sci. 1930, **41**, 85.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Nutrition 1931, **4**, 419.

[5] Compt. rend. 1920, **171**, 196.

[6] J. Biol. Chem. 1929, **82**, 465.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

SHOOTS OF THE GINSENG FAMILY

(*Araliaceæ*)

THE ginseng family, to which belong the English ivy (*Hedera*) and the drug ginseng (*Panax* spp.), is here represented by a single species used as food.

UDO

Aralia cordata Thunb. = *A. edulis* Sieb. et Zucc.

This Japanese shoot vegetable according to Fairchild[1] may be successfully grown in New England and southward to the Carolinas, also in the Sacramento and Puget Sound regions of the Pacific Coast.

CHEMICAL COMPOSITION.—Takeuchi[2] gives the following analysis of the shoots as grown in Japan: water 94.50, protein 1.10, pure protein 0.69, fat 0.42, reducing sugars 0.24, sucrose 0.07, starch 0.12, pentosans 0.41, fiber 0.85, galactan 0.03, tannin 0.33, and ash 0.55 per cent.

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[1] U. S. Dept. Agr. 1914, Bul. **84**.

[2] Bul. Col. Agr. Tokyo, 1907, **7**, 465.

LEAVES AND STEMS OF THE PARSLEY FAMILY

(*Umbelliferæ*)

LIKE crucifers, umbelliferous plants supply us with leaf vegetables as well as edible roots and seeds, and one at least of the species, celery, yields all three. Celery and Florence fennel are chiefly valuable for the blanched fleshy petioles, although the tender leaves also are edible; parsley, chervil, and honewort furnish edible leaf blades, petioles, and stems; angelica is grown chiefly for the hollow stem.

It seems somewhat paradoxical that the waxy whiteness and delicate flavor of blanched celery and Florence fennel, on the one hand, and the deep green and peculiar strong flavor of curled parsley, on the other, appeal to esthete and epicure.

CLASSIFICATION.—See Roots of the Parsley Family.

COMPARATIVE MACROSCOPIC STRUCTURE.—*Petiole, rachis,* and *petiolules* have a distinct channel on the inner side, which is especially marked at the base, where in Florence fennel they are also margined. They also have several ridges on the outer side passing into the nerves of the leaf blades.

The *leaves* are pinnately decompound, with usually three to seven leaflets which are variously divided or subdivided. All the divisions and subdivisions of Florence fennel are narrow, the leaflets being needle-shaped, whereas the leaflets of celery, honewort, parsley, and chervil are flat and in the last two species often curled.

COMPARATIVE MICROSCOPIC STRUCTURE.—All the species contain *volatile oil* as the aromatic constituent. This, as in umbelliferous roots, is located in *oleoresin cavities* and not, as in umbelliferous fruits, in jointed ducts (*vittæ*). The cavities accompany the fibrovascular bundles.

Hairs in the strict sense are absent except on the midrib, veins, and margins of chervil. Long papillæ occur on the midrib of honewort and short ones on the midrib of parsley. The *epiderm* on the ridges and veins consists of elongated cells which are transversely arranged in celery and Florence fennel and longitudinally arranged in parsley, chervil, and honewort, whereas between the ridges and veins it consists mostly of isodiametric, wavy-walled cells and stomata. The transverse arrangement is dependent on the maturity, being present on petioles and veins of all the plants when young, at which stage celery and Florence fennel are eaten.

A *collenchyma bundle* occurs beneath each ridge of the petiole and midrib and a *fibro-vascular* bundle further inward. In cross section the bundles form a crescent-shaped row.

Chief Structural Characters.—Leaves pinnately decompound. Petioles channeled on inner side, ribbed on outer side.

Volatile oil in oleoresin cavities. Collenchyma and fibro-vascular bundles beneath ridges. Epiderms smooth except for hairs on chervil and papillæ on honewort and parsley.

COMPARATIVE CHEMICAL COMPOSITION.—The characteristic flavor of each umbelliferous leaf vegetable is due to traces of its own peculiar *volatile oil*, but quantitative determinations are not available. Doubtless such figures, coupled with organoleptic tests, would furnish a basis for judging quality. Too much volatile oil imparts a disagreeable flavor and is more to be avoided than too little.

Aside from flavor, crispness and extreme whiteness of celery and Florence fennel are the chief desiderata. Analysis as ordinarily followed furnishes little information.

CHERVIL

Anthriscus Cerefolium Hoffm. = *Scandix Cerefolium* L.

Fr. Cerfeuil. Sp. Perifollo. It. Cerfoglio. Ger. Kerbel.

Several plants of the tribe *Scandiceæ* have leaves with an anise-like fragrance used for garnishing and flavoring salads and other dishes. Sweet cicely is a synonym for myrrh (*Myrrhis odorata* Scop.), an European plant seldom cultivated in the United States, but is also applied to several American species of *Osmorrhiza* (*Washingtonia*), the stems and roots of which are eaten by children.

Chervil, a plant native of the region about the Black and Caspian Seas, is grown in kitchen gardens of Europe and America.

MACROSCOPIC STRUCTURE.—In form the decompound *leaves* resemble those of parsley but are more delicate. The small oval leaflets vary from flat to curled, according to the variety.

MICROSCOPIC STRUCTURE.—Large, broad, stiff, unicellular, warty, pointed *hairs*, occurring along the midrib veins, and margins of the lower side of the leaf and on the ribs of the petiole, where they are longest, are the chief microscopic character distinguishing chervil from parsley. Other less striking distinctions are the narrower and longer *epidermal cells* over the ribs of the petiole and the absence of beads in he cell walls. Frequently only two accompanying cells surround each toma.

Chief Structural Characters.—Leaf decompound, with small oval divisions.

Large, broad, unicellular, warty, pointed hairs occur on veins of the ower side of the leaf and ribs of the petiole.

ANGELICA

Angelica Archangelica L. = *Angelica officinalis* Hoffm.

Fr. Angelique. Sp. Angélica. Ger. Angelika.

Angelica is a stately European plant, the root of which is used in medicine. In France the candied, decorticated internode of the stem, often colored bright green, is prepared on a commercial scale for use as a confection or for decorating pastries.

MACROSCOPIC STRUCTURE.—The *internodes* are hollow, finely corrugated, several centimeters in diameter, and reach great length.

MICROSCOPIC STRUCTURE.—The tissues of the internode are (1) *epiderm* of indistinct rows of polygonal cells which are longitudinally elongated except near the nodes where they are transversely elongated, (2) *hypoderm* of a few rows of weak collenchyma, (3) *cortex* of loose parenchyma with oleoresin ducts and robust fiber bundles over which are the ridges, (4) *starch sheath*, (5) *fibro-vascular bundles* with large vessels (100 μ or more) of various types, and (6) *pith*.

The process of preparation obscures the delicate elements such as oleoresin cavities and starch sheath.

Chief Structural Characters.—Internodes corrugated, decorticated in commercial product.

Epiderm cells transversely elongated at nodes, longitudinally elongated in internodes. Fiber bundles and large vessels (100 μ) conspicuous, oleoresin cavities obscured by method of preparation.

FLORENCE FENNEL

Fœniculum vulgare Mill. var. *dulce* Alef. = *F. dulce* DC.

Fr. Fenouil doux. Sp. Hinojo. It. Finocchio.
Ger. Römischer Fenchel.

A recent introduction into the United States to meet the demands of Italian residents, this plant, known also as sweet or Roman fennel, is being featured by seedsmen for general cultivation. As with celery, the petioles or leaf stalks together with the immature inner leaves are eaten, either raw or cooked, as a vegetable, and the strong, anise-flavored leaves are used in meat dishes.

MACROSCOPIC STRUCTURE.—On the outer side, the *petiole* has a rounded angle, on the inner side near the base a channel, narrower but deeper than that of celery, with a membranous rim several millimeters wide extending not only along the sides but also around the top. These winged channels, clasping alternately one over the other, form a flattened enlargement which is blanched by covering with earth. The *leaflets* of the decompound leaves have no broadened blades, the lobes being reduced to mere threads.

MICROSCOPIC STRUCTURE. Petiole.—Except for the membranous rim about the channel, the *epiderms* of which consist of longitudinally elongated cells without stomata, the structure is practically the same as that of celery.

Leaf Blade.—The midrib agrees in structure with the petiole. Although exceedingly narrow, the subdivisions of the leaf have the same general histological characters as celery leaf.

CHIEF STRUCTURAL CHARACTERS.—Petiole deeply channeled. Leaflets reduced to threads.

Microscopic structure similar to that of celery.

CELERY

Apium graveolens L.

Fr. Céleri. Sp. Ápio. It. Sedano. Ger. Sellerie.

Development of celery, now a common and popular relish vegetable, from a European plant has taken place in comparatively recent times. By breeding and studying suitable soil and cultural requirements, the texture, flavor, and whiteness of the stalks have been greatly improved.

MACROSCOPIC STRUCTURE.—The blanched, clasping *petiole* or leaf stalk is channeled on the inner side, especially at the base. A row of bundles is evident on the outer surface as ridges and upon breaking as strings. The compound *leaves* have three to seven leaflets on petiolules of variable length, the leaflets being three-lobed or divided and the broad divisions irregularly lobed and toothed. Since the mature green leaves are tough and rank flavored, only the leaf stalk and the yellow immature heart leaves are eaten.

MICROSCOPIC STRUCTURE. Petiole.—Between the ridges Fig. 70, I; Fig. 71) the cells of the *lower* (*outer*) *epiderm* are striate, more or less isodiametric, often arranged in longitudinal rows; stomata are numerous. On the ridges (II) the cells are transversely elongated, arranged side by side in distinct longitudinal rows; stomata are absent.

Under each ridge is a narrow bundle of *collenchyma cells.* The cells of the *mesophyl* (Fig. 71) are medium sized and isodiametric except about the fibro-vascular bundles and the oleoresin cavities where they are longitudinally elongated (*mes*), those immediately about the oleoresin cavities being narrow and filled with granular contents. *Oleoresin cavities* are easily found in cross section because of these surrounding narrow cells. In longitudinal section they are seen to be elongated (*ol*) and to contain drops of volatile oil. In the *fibro-vascular bundles* of the older petioles broad (up to 25 μ), pitted (*pi*), and reticulated (*ret*) vessels, also spiral vessels (*sp*), often with several strands, are conspicuous.

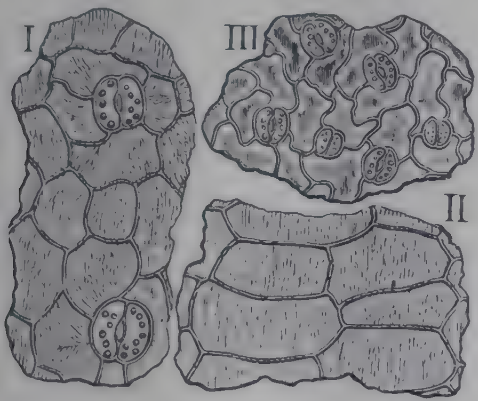

FIG. 70.

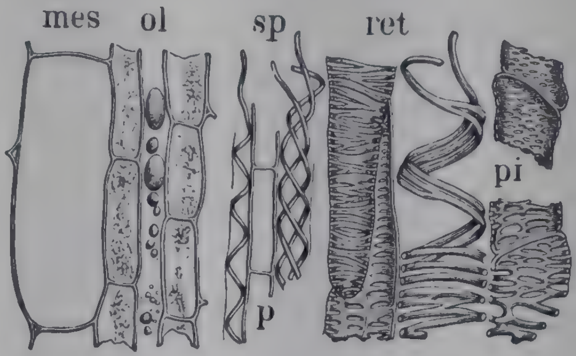

FIG. 71.

FIG. 70.—Celery. I outer epiderm of large petiole between ridges; II over prominent ridge. III outer (lower) epiderm of very young leaf. × 160. (K.B.W.)

FIG. 71.—Celery. Elements of petiole in longitudinal section. *mes* mesophyl; *ol* oleoresin cavity flanked by elongated secreting cells; *sp* spiral, *ret* reticulated, and *pi* pitted vessels; *p* xylem parenchyma. × 160. (K.B.W.)

In the bundles of younger petioles narrow spiral vessels predominate. Isodiametric or somewhat elongated cells and occasional stomata make up the *epiderm* on the inner concave surface.

Leaf Blade.—Only the young etiolated leaves need be considered. The *lower* (*outer*) *epiderm* (Fig. 70, III) consists chiefly of wavy-walled cells and numerous stomata. A typical loose parenchyma, but without chlorophyl grains, forms the ground tissue of the *mesophyl.* The *xylem* of the fibro-vascular bundle is made up mostly of delicate spirals. Beneath the bundles *oleoresin cavities* are noticeable. Straight or slightly wavy-walled cells and stomata make up the *upper* (*inner*) *epiderm.*

CHIEF STRUCTURAL CHARACTERS.—Petiole with ridges on outer side, channel on inner side broadening at base.

Lower epiderm over veins and ridges of transversely elongated cells elsewhere of isodiametric cells interspersed with stomata. Collenchyma groups and bundles beneath the ridges. Vessels pitted, reticulated, spiral-reticulated, and spiral; small spiral vessels predominating in leaves and young petioles. Oleoresin cavities in petiole and leaf blade.

CHEMICAL COMPOSITION.—Analyses of the edible part of 5 samples, as given by Atwater and Bryant,[1] and of one sample each by v. Schleinitz[2] and Agcaoili,[3] also of petiole, leaves, and root (recalculated) by Dahlen,[4] follow:

COMPOSITION OF CELERY

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
A. and B.:							
Min.	93.1	1.0	....	0.1	3.0		0.9
Max.	95.0	1.4	....	0.2	4.6		1.1
Aver.	**94.5**	**1.1**	....	**0.1**	**3.3**		**1.0**
v. Schleinitz	90.54	1.34	1.09	0.27	5.87	1.01	0.97
Agcaoili	92.72	1.65	....	0.32	2.89	0.86	1.56
Dahlen:							
Petiole	89.57	0.88	....	0.34	6.56*	1.24	1.41
Leaves	81.75	4.60	....	0.79	9.03†	1.40	2.43
Root	84.09	1.48	....	0.40	11.79	1.40	0.84

* Sugars 0.62%. † Sugars 1.24%.

Nitrogen Distribution in Healthy and Diseased Celery.—Klotz,[5] in studying the influence of *Septoria* leaf spot on composition, determined the nitrogen distribution in healthy and diseased stalks.

	Ammonia N	Nitric N	Nitrous N	Hydrolyzable N	Acid amide N	Humin N	Total amino N	Protein N	Non-protein N
	%	%	%	%	%	%	%	%	%
Healthy	0.3	5.8	absent	88.8	13.5	9.6	47.1	67.8	32.1
Diseased	1.3	5.7	present	84.9	11.8	10.9	43.5	72.6	27.1

Volatile Oil.—See Celery Seed, Volume III.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Landw. Jahrb. 1918, **52**, 131.

[3] Philippine J. Sci. 1916, **11**, 91.

[4] Landw. Jahrb. 1874, **3**, 723.

[5] J. Agr. Res. 1925, **31**, 287.

Carbohydrates.—Wittmann[1] found 1.60 per cent of *pentosans*.

Dahlen[2] in petiole, leaf, and root found respectively: 0.62, 1.26 and, 0.77 per cent of *sugars*.

Obaton[3] states that *mannite* occurs in all parts of the plant but is produced only when the chlorophyl grains are functioning. He determined the relative amounts of reducing sugars, sucrose, and mannite in petioles, leaves, and roots during growth.

Mineral Constituents.—Herapath,[4] in the young shoots on the dry basis, found 16.27 per cent of crude ash containing 10.96 per cent of carbon dioxide and 14.49 per cent of pure ash. Richardson[5] found in celery root (celeriac), on the dry basis, 12.59 per cent of crude ash, containing 8.08 per cent of carbon dioxide, and 11.04 per cent of pure ash. Analyses of the pure ash by the authors named follow:

COMPOSITION OF CELERY ASH

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
Young shoots	33.14	19.33	13.06	......	......	14.39	1.18	1.85	22.14
Root........	43.19	....	13.11	5.82	1.41	12.83	5.58	3.85	15.87

Minor Mineral Constituents. *Iron.*—Celery 7.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[6] Celery, 2 samples, 3.5, 8.0, fresh basis (Toscani and Reznikoff).[7]

Manganese.—Celery 22.7 mg. per kilo, dry basis (Quartaroli).[8]

Copper.—Celery, fresh 2, dry basis 21.9 mg. per kilo (Guérithault).[9] Celery 38.8 mg. per kilo, dry basis (Quartaroli).[8] Celery 0.1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[10]

Arsenic.—Celery 0.2 mg. per kilo, fresh basis (Jadin and Astruc).[11] Determinations of arsenic by Longfield-Smith[12] in 548 samples (some obviously sprayed) show a range from none to 0.2824 grain of As_2O_3 per pound (30.5 mg. of As per kilo) and nearly 20 per cent of the samples contained more than 0.01 grain of As_2O_3 per pound (1.08 mg. of As per kilo), the legal limit.

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[1] Z. landw. Versuchsw. Oesterr. 1901, **4**, 131.

[2] Loc. cit.

[3] Compt. rend. 1929, **188**, 77; Rev. gén. botan. 1929, **41**, 282, etc.

[4] Wolff: Aschenanalysen, p. 127.

[5] Ann. 1848, **67**, 377.

[6] J. Biol. Chem. 1928, **78**, 215.

[7] J. Nutrition 1934, **7**, 79.

[8] Ann. chim. appl. 1928, **18**, 47.

[9] Compt. rend. 1920, **171**, 196.

[10] J. Biol. Chem. 1929, **82**, 465.

[11] Compt. rend. 1912, **155**, 291.

[12] Florida Agr. Exp. Sta. 1932, p. 35.

HONEWORT

Cryptotænia Canadensis DC. var. *japonica* Mak.

Jap. Mitsuba. Chin. Asp-ye-kan.

As the Latin name denotes, the type of this species is a native of the Western Hemisphere where it is regarded as of no economic value. The edible variety, according to M. Kondo,[1] grows wild in China and Japan and is much cultivated in the latter country as a garden vegetable, the young, tender, aromatic leaves and stems being eaten cooked or as salad.

The following brief description of the leaves is based on an examination of wild material gathered in Wilton, Conn. Kondo has fully described the structure of the fruit and seed.

MACROSCOPIC STRUCTURE.—The *leaflets* of the trifoliate leaves are ovate, up to 9 cm. long, pointed, twice serrate, on a long *petiole*. Kondo's illustration of the variety corresponds with this description except that the leaflets are not so pointed.

MICROSCOPIC STRUCTURE. Petiole.—As in other members of the family, the *hypoderm* is collenchymatous, the *fibro-vascular bundles* have starch sheaths, and the *mesophyl* contains oleoresin cavities.

Leaflet.—Both *epiderms* have more or less polygonal cells which on the lower surface are often wavy-walled. Stomata are numerous. Over the midrib of the *lower epiderm* are occasional papillæ which are almost long enough to be designated as hairs.

CHIEF STRUCTURAL CHARACTERS.—Leaves trifoliate with long petioles; leaflets twice serrate.

Lower epiderm with papillæ; mesophyl with oleoresin cavities.

CHEMICAL COMPOSITION.—Chung and Ripperton[2] give a single analysis of honewort cultivated for the local market in Hawaii:

COMPOSITION OF HONEWORT (CHUNG AND RIPPERTON)

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
89.53	2.33	0.23	4.37	1.45	2.09

Mineral Constituents.—The above-named authors found calcium 0.114, iron 0.0149, and phosphorus 0.061 per cent; also alkalinity of ash, calculated as cubic centimeters of normal acid per 100 grams of fresh vegetable, 23.9.

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[1] B. Ohara Inst. Landw. Forsch. 1919, **1**, 416.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

PARSLEY

Petroselinum sativum Hoffm. = *Apium Petroselinum* L.

Fr. Persil. Sp. Perejil. It. Prezzemolo. Ger. Petersilie.

From the wild plant growing about the Mediterranean Sea, strains of parsley have been bred in comparatively modern times to furnish on the one hand an edible root, similar to the carrot, and on the other hand beautifully lobed and curled deep green foliage valuable alike for flavor and garnish.

Hartwich[1] and other German authors warn against planting any but the curled variety (*crispum* (Mill.) DC.) since the leaves of the poisonous *Æthusa Cynapium* L., which grows wild in central Europe, are easily mistaken for those of the non-curled variety.

MACROSCOPIC STRUCTURE.—Curled parsley differs from the wild form and the variety developed for the root in having the *leaves* two or three times decompounded and the lobes curiously bent toward the inner side—the side corresponding to the grooved side of the petiole—so as to give the whole a mossy appearance. For example, in the two lower of four pairs of branches from the midrib of a specimen examined, secondary and tertiary branching of both the midrib and the leaf blade, a total of six divisions, was evident; in the third pair, however, only secondary and in the top or fourth pair only primary branching was clearly defined, the lobing being the same throughout. Branching and lobing to such an extent, coupled with the considerable breadth of the lobes, necessitates curling to avoid overlapping and to bring each lobe into the sunlight. This is especially important when the petiole and the branches have not reached their full length.

It frequently happens that the lower pair of secondary branches of the petiole, particularly those belonging to the second pair of primary branches, instead of being some distance from the petiole arise directly from it, making the number of primary branches at this point apparently six instead of two. Such an abnormality tends also to bring the leaf blades closer together, necessitating greater curling. The obtuse ends of the ultimate lobes, compared for example with the parted lobes of carrot leaf, contribute further to the crowding.

MICROSCOPIC STRUCTURE. Petiole (Fig. 72; Fig. 73, I).—The cells of the *epiderm* are longitudinally elongated, especially over the ridges. Stomata occur between the ridges. A *collenchyma* bundle (Fig. 72, *col*) is present beneath each ridge. Between the collenchyma bundles the *mesophyl* contains chlorophyl grains (*ch*), but further inward the cells (*mes*) have only colorless contents. Adjoining the outer side of each fibro-vascular bundle is a longitudinally elongated *oleoresin cavity* (*ol*) containing drops of volatile oil. Each *fibro-vascular bundle* consists of a group of spiral, annular, reticulated, and spiral vessels (*xy*) with phloem (*ph*) on the outer side and a ring of bast fibers about the whole.

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[1] Real-Enzykl. ges. Pharm. Berlin, 2. Aufl. 1908, **10**, 141.

Leaf Blade.—The *lower* (*outer*) *epiderm* (Fig. 73, II) between the veins consists of thin, wavy-walled, isodiametric cells and numerous stomata, many with horns. On the veins the cells are longitudinally elongated, with straight beaded walls, and stomata are absent. Short papillæ occur over the midrib. Typical loose chlorophyl parenchyma forms the ground tissue of the *mesophyl*. *Fibro-vascular bundles*, with mostly spiral and annular vessels, form the main tissue of the veins. *Oleoresin cavities*, such as occur in the petiole, accompany the bundles. The *upper* (*inner*) *epiderm* is like the lower epiderm except that the walls are not quite so wavy.

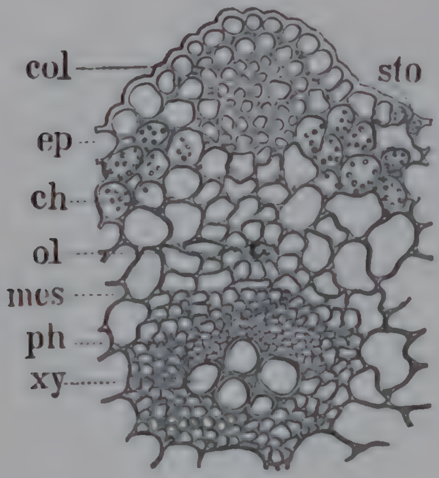

FIG. 72.

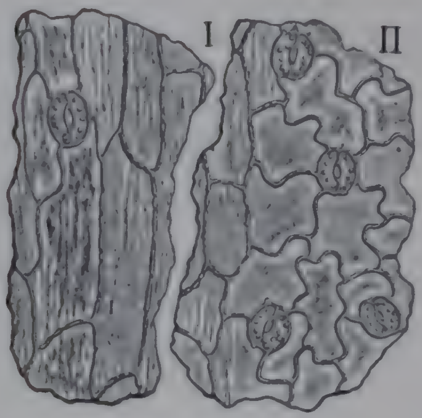

FIG. 73.

FIG. 72.—Parsley. Very small petiole in cross section. *ep* epiderm with *sto* stoma between ridges; *col* collenchyma in ridge; *ch* chlorophyl-containing mesophyl between ridges; *ol* oleoresin cavity; *mes* colorless mesophyl; *ph* phloem; *xy* xylem. × 160. (K.B.W.)

FIG. 73.—Parsley. I outer epiderm of petiole; II lower epiderm of leaf, showing at left elongation of cells over vein. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaves pinnately decompounded, much branched, lobed, and curled.

Epidermal cells of petiole and veins of leaf longitudinally elongated, those between the veins of leaflets isodiametric, wavy-walled; stomata, often with horns. Fibro-vascular bundles of petiole and veins with mostly spiral and annular vessels; bundle surrounded by bast fibers. Oleoresin cavities on phloem side of bundles. Mesophyl of typical chlorophyl cells.

CHEMICAL COMPOSITION.—Agcaoili[1] gives the following analysis of parsley:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
85.7	3.82	1.39	4.82	1.52	2.75

Volatile Oil.—See Parsley Seed, Volume III.

Minor Mineral Constituents. *Iron.*—Leaf, 2 samples, 192 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Copper.—Leaf 2.1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[3]

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[1] Philippine J. Sci. 1916, **11**, 91.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Ibid. 1929, **82**, 465.

LEAVES AND STEMS OF THE MORNING-GLORY FAMILY

(*Convolvulaceæ*)

Swamp cabbage is a common oriental leaf vegetable belonging to the same family as the sweet potato described under Root Vegetables.

SWAMP CABBAGE

Ipomœa reptans Poir. et Cog.

Chin. Ung-choi.

Swamp cabbage is stated to be a native of India. Chung and Ripperton's illustration and description of the plant as found on the Hawaiian market[1] correspond with the vegetable bought in New York Chinatown by the writers under the name of *hung-toi,* which phonetically is much like *ung-choi.*

MACROSCOPIC STRUCTURE.—The following is based on Chung and Ripperton's description. *Stem* light yellowish green, up to 1.3 cm. in diameter, with hollow internodes and often white roots about the nodes of the lower submerged part of the plant. *Leaf* light green, thin, smooth, ovate-cordate or sagittate, up to 10 cm. long.

MICROSCOPIC STRUCTURE. Leaf.—Both *epiderms* are practically alike. The cells are small, thin-walled, and isodiametric, except over the veins where they are elongated with striated cuticle. Numerous stomata and small capitate hairs are also present. The head cells of the hairs vary in number up to twelve or more. The *mesophyl* is characterless except for oxalate rosettes occurring here and there, especially near the big veins.

CHEMICAL COMPOSITION.—The samples represented by the analyses in the following table were collected and analyzed by Agcaoili[2] in the Philippines, Sherman and Wang[3] in Peiping, and Chung and Ripperton[4] in Hawaii under different foreign names:

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[1] Hawaii Agr. Exp. Sta. 1929, Bul. **60.**

[2] Philippine J. Sci. 1916, **11,** 91.

[3] Ibid. 1929, **38,** 69.

[4] Hawaii Agr. Exp. Sta. 1929, Bul. **60.**

Composition of Swamp Cabbage

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
gcaoili:						
Cancong	89.70	4.25	0.04	3.64	0.70	1.67
. and W.:						
Weng ts'ai	93.39	1.19	0.29	1.19	1.11	1.42
. and R.:						
Ung-choi	92.26	1.94	0.14	3.31	1.13	1.22

Mineral Constituents.—Chung and Ripperton[1] found calcium 0.077, ron 0.0032, and phosphorus 0.064 per cent; also alkalinity of the ash 4.3 expressed as cubic centimeters of normal acid per 100 grams of resh vegetable.

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[1] Loc. cit.

LEAVES AND STEMS OF THE BORAGE FAMILY

(*Boraginaceæ*)

Although this family claims several well-known drug plants and ornamentals, only one species, borage, is worthy of mention as a food.

BORAGE

Borago officinalis L.

Fr. Bourrache. Sp. Borraja. It. Boragine. Ger. Borretsch.

Only very young leaves of borage, a Mediterranean plant eaten raw and cooked, are edible, and these are often so hairy as to suggest green velvet. The plant can better lay claim to being an indirect human food as bees delight in the showy blue flowers.

MACROSCOPIC STRUCTURE.—The *leaves* are oval-lanceolate, crenate, and irregularly toothed. The veins form a series of loops near the margin. Hairs are numerous on both sides, being longest on margins and veins.

MICROSCOPIC STRUCTURE.—The *hairs* are long (up to 3 mm.), straight, thin-walled, warty, gradually tapering from the base to the apex. They are usually, if not always, unicellular since what appear to be cross partitions at places where there is an accumulation of protoplasmic matter are doubtless only folds in the walls. About the globular base the *epidermal cells* form an elevation.

Chief Structural Characters.—Leaves oval-lanceolate, hairy. Hairs up to 3 mm., straight, tapering, thin-walled, warty.

LEAVES OF THE VALERIAN FAMILY

(*Valerianaceæ*)

This family, to which belongs valerian, a well-known root drug, is represented among food plants by corn salad.

CORN SALAD

Valerianella olitoria Pall.

Fr. Blanchette. Sp. Valerianilla. It. Dolcetta. Ger. Stechsalat.

The plant, also known as fetticus and lamb's lettuce, is a weed in European grain fields but has been improved by cultivation. One variety produces compact heads.

Italian corn salad (*V. eriocarpa* Desv.), a native of southern Europe, has slightly toothed and more hairy leaves than the northern species.

MACROSCOPIC STRUCTURE.—*Root leaves* (the only edible part) of the common variety are spoon-shaped with entire margins and several parallel veins connected by lateral branches. To the naked eye they are practically smooth. The *flowers* are small, bluish white, and borne in terminal cymes on leafy stalks.

MICROSCOPIC STRUCTURE. Leaf.—The cells of the *lower epiderm* (Fig. 74) have much more wavy walls than those of the upper, the turns being often angular. On the veins they are elongated and finely striate. *Multicellular hairs* (t^1) occur over the whole surface of the young leaf, less often on the veins, collapsing or disappearing during further growth; the stalk consists of one or two cells, the cap of several cells, all with thin walls. Short, broad, blunt, thin-walled, faintly warty *unicellular hairs* (t^2) occur chiefly on the veins. The *mesophyl* is characterless. The cells of the *upper epiderm* between the veins are nearly isodiametric with thin, somewhat wavy walls. Stomata are numerous, sometimes two being in contact, but hairs are less abundant than on the lower epiderm.

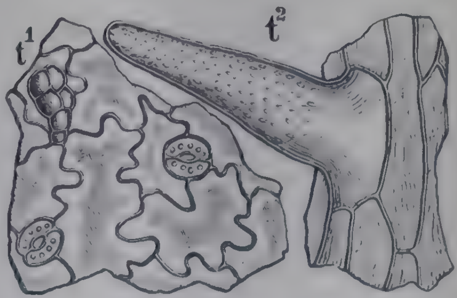

Fig. 74.—Corn Salad. Lower epiderm of leaf in surface view. Left, between veins showing stomata and t^1 multicellular hair; right, over midrib showing t^2 unicellular hair. × 160. (K.B.W.)

Chief Structural Characters.—Leaves spoon-shaped, with several parallel veins.

Epidermal cells with wavy walls; stomata numerous; hairs partly small, weak, multicellular, capitate, partly broad, blunt, faintly warty, unicellular.

CHEMICAL COMPOSITION.—Dahlen[1] found the following:

Water	Protein	Fat	N-f. ext.	Sugars, reducing	Fiber	Ash
%	%	%	%	%	%	%
93.41	2.09	0.41	2.73	trace	0.57	0.79

Minor Mineral Constituents. *Zinc.*—Leaves 5.4 mg. per kilo, fresh basis (Bertrand and Benzon).[2]

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[1] Landw. Jahrb. 1874, **3**, 723.

[2] Bul. soc. hyg. aliment. 1928, **16**, 457.

LEAVES OF THE COMPOSITE FAMILY

(*Compositæ*)

THE salad vegetables of this family belong to the tribe *Cichoriaceæ* (*Liguliforæ*), to which tribe also belong the commonest composite root vegetables. Of these, lettuce (*Lactuca sativa* L.) is by far the most important, although endive (*Cichorium Endivia* L.) and chicory (*C. Intybus* L.), which includes witloof and barbe de capucin, are highly esteemed. Leaves of the dandelion (*Taraxicum officinale* Weber), when bleached, are suitable for salad, but ordinarily, without bleaching, are used only as a pot herb. The edible part of cardoon (*Cynara Cardunculus* L.) of the tribe *Cynareæ* is the fleshy midrib.

COMPARATIVE MACROSCOPIC STRUCTURE.—*Leaves* of the different species vary greatly in form and crinkling, but in general lettuce has broad, entire leaves and the other species narrow, lobed, toothed, or, in the case of cardoon, spiny leaves. All have prominent succulent midribs which form a considerable part of the edible portion.

COMPARATIVE MICROSCOPIC STRUCTURE.—As in composite roots, *latex tubes*, accompanying the bundles, are the characteristic cellular elements. These, as well as other *mesophyl* tissues, differ little in the various species; the *epiderms*, however, especially as regards the hairs and emergences, show some marked points of difference.

In all the species, the *epidermal cells* over the midrib and veins are longitudinally elongated, with straight walls, whereas those between the veins are isodiametric with wavy or irregular walls. The epidermal cells of lettuce are as a rule larger than those of the other species.

Jointed hairs occur on the upper (inner) epiderm of all species and on the lower (outer) epiderm of all but lettuce. The end cells of these hairs in dandelion are commonly larger than the others and in cardoon very much longer. *Emergences* or emergence-like hairs are found on the midrib and veins of the lower epiderm of lettuce and endive; *spines* are present on cardoon at the tip of each lobe of the leaf. *Capitate hairs*, with double row of cells, are characteristic of lettuce and cardoon.

COMPARATIVE CHEMICAL COMPOSITION.—The usual proximate analysis is of little practical value. It fails to take account of *latex*, the characteristic constituent of composite leaves and roots, and *tannin substances* to which over-developed lettuce, endive, chicory, and dandelion greens owe their bitter taste.

LETTUCE

Lactuca sativa L.

Fr. Laitue. Sp. Lechuga. It. Lattuga. Ger. Lattich.

The evidence appears to be conclusive that garden lettuce was derived from the species *L. Scariola* L. which grows wild in central and southern Europe, northern Africa, and western Asia. It was grown by the Greeks and Romans before the Christian era and according to Reinhardt[1] in Persia in the sixth century B.C. but was not introduced into the Orient, according to Bretschneider,[2] until centuries later.

The numerous varieties in common cultivation are grouped as (1) common and (2) cos or romaine lettuce. Two other groups—cut-leaved and narrow-leaved—are of less importance. Kondo[3] states that the native Japanese varieties are not numerous, the best known being *kakitchischa.* In common lettuce the heads may be loose or compact (" butterhead "). In all varieties it is the sessile root leaves that are eaten. When the stalk runs up to seed, the leaves are disagreeably bitter and also tough.

MACROSCOPIC STRUCTURE.—All varieties have pinnately veined, obovate *leaves,* the midrib being very prominent, and the veins or primary branches from the midrib preserve their identity for a considerable distance—in the middle at least two-thirds of the distance to the edge—before they are lost in the cross branching. Leaves of varieties of common lettuce vary greatly in color—light to dark green, mottled with brown or purple, etc.—size, texture, nature of margin, and degree of crinkling. The chief distinctions of cos from common lettuce are that the leaves are longer, narrower, stiffer, and more erect, furthermore the heads are club-shaped. The midrib is very prominent, the nerves and nervelets are numerous, and the reticulations are distinct.

A fresh break or cut through the midrib causes the white latex to exude in drops. This is bitter to the taste and when dried constitutes *lactucarium* (lettuce opium) which, although obtainable from all varieties, is usually prepared as a drug from *L. virosa.*

MICROSCOPIC STRUCTURE.—Common lettuce, both loose-leaf, and compact head, and cos lettuce resemble each other so closely that one description, with exceptions noted, suffices.

Leaf.—The *epiderms* (Figs. 75 and 76) consist of (1) sinuous- or straight-walled cells, (2) numerous round stomata, (3) hairs, and in most varieties (4) stiff emergences on the under side standing out at right angles to the midrib. In brown or purple varieties the color is in solution in the epiderm.

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[1] Kulturgeschichte der Nutzpflanzen, 1911, **4**, I, 308.

[2] Study and Value of Chinese Botanical Works, Foochow, 1870, p. 17.

[3] Ber. Ohara. Inst. landw. Forsch. 1919, **1**, 433.

Two kinds of *hairs* are present: (1) small, thin-walled, capitate, with cells of head and stalk in two rows (t^1), found on both outer and inner epiderm; and (2) very long, jointed, often more or less shriveled, found only on the inner epiderm (Fig. 75). In the hard center of compact head varieties, this second type of hair may be branched, the attachment of each succeeding joint being just below the apex of the preceding one. The cells on the very edge of the leaf often extend to form small papillæ but not true hairs. Blunt pointed *emergences* (Fig. 76, t^2), varying greatly in size, are so large on cos lettuce that they may be seen with the naked eye. The epidermal cells of an emergence are thin-walled and usually more or less elongated in the direction of the axis.

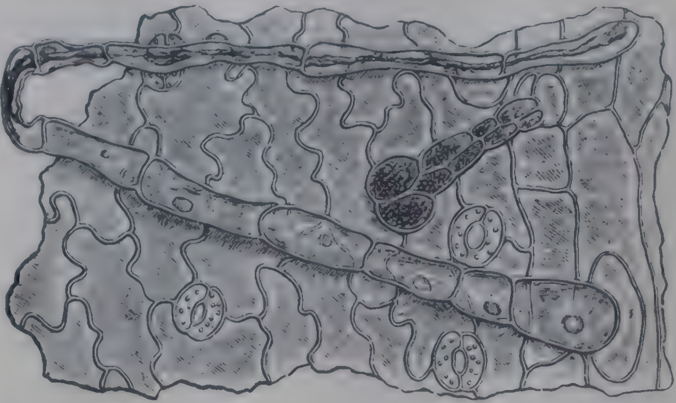

Fig. 75.—Lettuce. Upper (inner) epiderm of leaf in surface view showing sinuous-walled cells, stomata, and straight-walled cells near midrib with capitate hair and partially shriveled jointed hair. × 160. (K.B.W.)

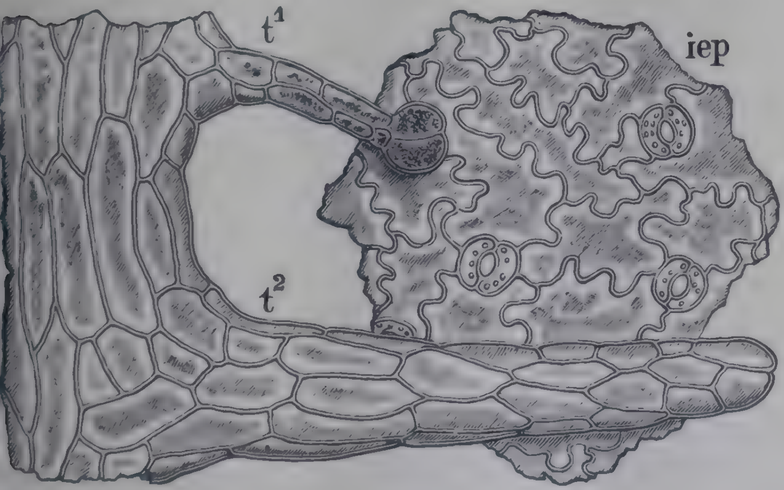

Fig. 76.—Lettuce. Lower (outer) epiderm of leaf in surface view. *iep* sinuous-walled cells between veins and stomata; t^1 capitate hair and t^2 small emergence arising from elongated cells over midrib. × 160. (K.B.W.)

A *mesophyl* of loose chlorophyl-bearing parenchyma forms the bulk of the leaf tissue. Near the midrib and veins the cells are elongated longitudinally. No sharply differentiated *palisade layer* is evident, although the mesophyl cells adjoining the inner epiderm are in closer contact and slightly elongated.

As seen in cross section of the midrib, the *fibro-vascular bundles* (Fig. 77) are arranged in a semicircle along the outer (lower) side with xylem toward the inner (upper) side. They consist of (1) *xylem* with annular (*an*), spiral (*sp*), reticulated (*ret*), and scalariform (*sc*) vessels in radiating rows, (2) *phloem* with sieve tubes (*s*) evident without special treatment, (3) *parenchyma* (*p*), (4) *collenchyma cells* (*col*) in a group outside of the sieve tubes, (5) anastomosing *latex tubes* (*l*) regularly arranged outside of collenchyma just within (6) the *bundle sheath* (*bs*) which surrounds the whole.

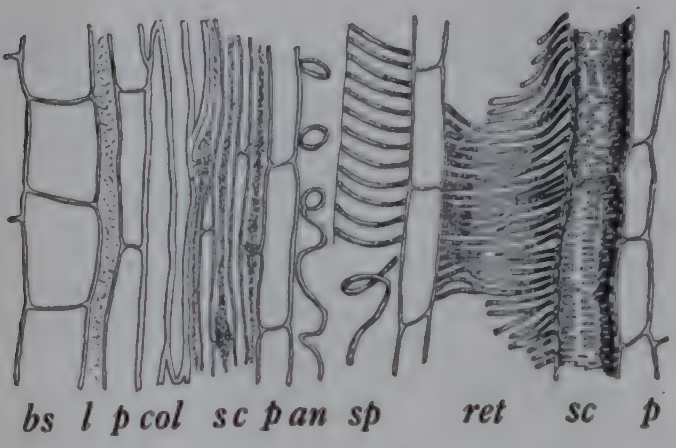

FIG. 77.—Lettuce. Vascular bundle of midrib in longitudinal section. *bs* bundle sheath; *l* latex tube; *p* parenchyma; *col* collenchyma; *s* sieve tubes; *c* companion cells; *an* annular, *sp* spiral, *ret* reticulated, and *sc* sclariform vessels. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaf obovate, variously margined, often crinkled; midrib prominent.

Both epiderms with large, isodiametric, wavy-walled cells between veins, straight-walled, elongated cells on veins and midrib, and two-rowed capitate hairs near veins and midrib; outer epiderm with emergences on midrib; inner epiderm with jointed hairs. Mesophyl of chlorophyl parenchyma with fibro-vascular bundles accompanied by collenchyma and latex tubes; vessels large and small of various types.

CHEMICAL COMPOSITION.—The analyses reported by Richardson,[1] as given in the table on the following page, show in the later stages not only a decrease in water content but also an increase of nitrogen-free extract and fiber in the dry matter at the expense of protein, fat, and ash, the leaves being consequently tough and fibrous. An analysis by v. Schleinitz[2] and one by Chung and Ripperton[3] of loose-head Black Seeded Simpson grown in Hawaii are also included.

Influence of Soil on Nitrogen Content.—In experiments on the percentages of nitrogen in tops and roots of head lettuce grown in the greenhouse, Noyes[4] found that the nitrogen content of the tops differed both with the soil and the fertilizer and that the same fertilizer produced different effects with different soils. In bank sand the average nitrogen in the air-dry tops was 2.16 per cent with a variation of 0.95 per cent, in bank sand and manure mixture it was 3.58 per cent with a variation of 0.41 per cent, and in brown silt loam it was 3.75 per cent with a variation of 0.66 per cent. The average water content in the fresh tops for the three soils was respectively: 90.5, 90.9, and 92.5 per cent.

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[1] U. S. Dept. Agr. Rep. 1883, p. 241.

[2] Landw. Jahrb. 1918, **52**, 131.

[3] Hawaii Agr. Exp. 1929, Bul. **60**.

[4] J. Ind. Eng. Chem. 1918, **10**, 621.

COMPOSITION OF LETTUCE

	Weight	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	g.	%	%	%	%	%	%
Richardson:							
Entire plant:							
May 18	1	94.39	1.47	0.30	1.80	0.55	1.49
June 9	96	95.02	1.15	0.34	2.03	0.41	1.05
June 26	256	94.59	1.45	0.37	1.69	0.84	1.06
July 3	266	94.31	1.42	0.46	1.88	0.99	0.94
July 14	287	91.50	1.82	0.60	3.77	1.09	1.22
Stem:							
July 28 (41%)	287*	88.46	0.88	0.65	6.15	2.68	1.18
Leaves:							
July 28 (59%)	287*	86.28	2.27	0.95	6.22	2.57	1.71
v. Schleinitz	....	95.43	1.43†	0.24	1.59	0.54	0.77
C. and R.	....	95.94	0.97	0.11	1.56	0.58	0.84

* Whole plant. † Pure protein 1.10%.

Acids.—Results on organic acids, as determined by Nelson and Mottern,[1] are as follows: *oxalic* 0.011, *l-malic* about 0.065, and *citric* about 0.048 per cent.

Mineral Constituents.—The following analyses reported by Wolff[2] and by Haskins[3] are of interest, although it is uncertain as to the exact meaning of " common " and " head." For comparison with the first analysis, the second should be multiplied by 2 since the lettuce contains twice as much dry matter.

COMPOSITION OF LETTUCE ASH
(Parts per hundred of the fresh material)

	Water	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
Common (Wolff)	94.0	0.37	0.08	0.05	0.02	0.07	0.03	0.13	0.04
Head (Haskins)	97.0	0.23	0.02	0.03	0.01	0.03	......	......	......

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[1] J. Am. Chem. Soc. 1931, **53**, 1909.

[2] Aschenanalysen, 1889.

[3] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

In lettuce grown in Hawaii, containing 4 per cent of dry matter, Chung and Ripperton[1] found calcium 0.028 per cent (CaO 0.39 part per thousand), phosphorus 0.022 per cent (P_2O_5 0.50 part per thousand), and alkalinity of ash 6.8 in terms of cubic centimeters of normal acid per 100 grams of fresh vegetable.

Minor Mineral Constituents. *Iron.*—Leaves 3 mg. per kilo, fresh basis (Sherman).[2] Leaves, 9 samples, 425 to 4830, aver. **2110** mg. per kilo, dry basis (Remington and Shiver).[3] Leaves 30 mg. per kilo, fresh basis (Chung and Ripperton).[4] Leaves 18.7, head 4.2 mg. per kilo, fresh basis (Peterson and Elvehjem).[5] Leaves, 2 samples, 9.0, 12.8, head, 4 samples, 3.2 to 6.0 mg. per kilo, fresh basis (Toscani and Reznikoff).[6]

Aluminum.—Head 11.8 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[7] Green leaves 260, heart 100 mg. per kilo, dry basis (Bertrand and Lévy).[8]

Manganese.—Leaves 3.92 mg. per kilo, dry basis (Quartaroli).[9] Leaves, 8 samples, 68.2 to 165.2, aver. **118.4** mg. per kilo, dry basis (Remington and Shiver).[3] Leaves 167 mg. per kilo, dry basis (Peterson and Skinner).[10]

Copper.—Leaves 36.3 mg. per kilo, dry basis, equivalent to 2.00 fresh basis (Guérithault).[11] Leaves 40, romaine 14 mg. per kilo, dry basis (Maquenne and Demoussy).[12] Leaves, 6 samples, 6.1 to 16.6, aver. **10.9** mg. per kilo, dry basis (Remington and Shiver).[3] Leaves, 2 samples, 0.6, head, 1 sample, 0.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[13]

Zinc.—Cabbage-lettuce leaves 4.7, Romaine lettuce leaves 1.8 mg. per kilo, fresh basis (Bertrand and Benzon).[14] Lettuce 5.1 to 8.9 mg. per kilo, dry basis (Hubbell and Mendel).[15]

Iodine.—Present in head lettuce (Winterstein).[16]

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[1] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[3] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[4] Loc. cit.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] J. Nutrition 1934, **7**, 79.

[7] Am. J. Physiol. 1929, **90**, 72.

[8] Bul. soc. hyg. aliment. 1931, **19**, 359.

[9] Ann. chim. appl. 1928, **18**, 47.

[10] J. Nutrition 1931, **4**, 419.

[11] Compt. rend. 1920, **171**, 196.

[12] Ibid. 1920, **170**, 87.

[13] J. Biol. Chem. 1929, **82**, 465.

[14] Bul. soc. hyg. aliment. 1928, **16**, 457.

[15] J. Biol. Chem. 1927, **75**, 567.

[16] Z. physiol. Chem. 1918, **104**, 54.

ENDIVE

Cichorium Endivia L.

Fr. Escarole. Sp. Escarola. It. Indivia. Ger. Endivie.

Two kinds are grown as Autumn salad plants, the curled (chicorée crépue) and the broad-leaved Batavian (escarole). Both, in the opinion of some botanists, are cultivated forms either of *C. divaricatum* Schousboe (*C. pumilum* Jacq.), which grows wild in the Mediterranean region, or else of some other parent species.

Although often somewhat bitter, the flavor is usually acceptable. The leaves are firm but not tough. By tying up the head the center is blanched, which adds greatly to its appearance, flavor, and texture.

MACROSCOPIC STRUCTURE.—Primary, secondary, and tertiary lobes of curled endive are so deeply cut or parted that the white midrib forms the chief part of the *leaf*. The ultimate divisions are sharp-pointed and the whole leaf is much curled. The firmness of the leaf is due partly to the preponderance of midrib and partly to turgescence. Broad-leaved Batavian endive has a greater proportion of chlorophyl-bearing tissues which on blanching are yellow.

MICROSCOPIC STRUCTURE.—Only the palatable inner blanched root leaves are considered.

Leaf (Fig. 78).—Over the midrib and veins (I) both *epiderms* consist of (1) longitudinally elongated cells with beaded walls, (2) narrow, jointed blunt, thin-walled hairs, and (3) emergence-like hairs with several rows of striate cells at the base. Between the veins (II) the cells are isodiametric with more or less wavy walls, and only jointed hairs are present. On the margins occur short emergence-like hairs, often as broad as long. Stomata are present except over the middle of the midrib and veins.

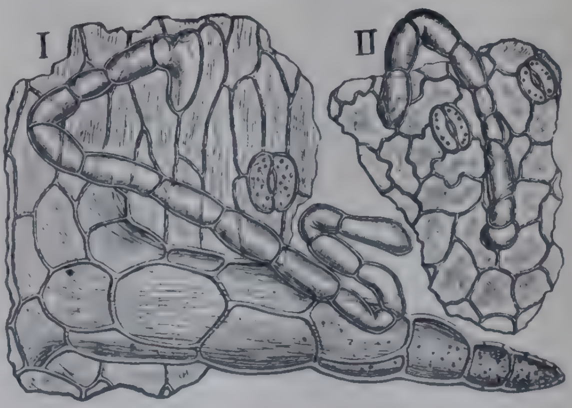

Fig. 78.—Endive. Lower epiderm of leaf in surface view. I over vein showing jointed and emergence-like hairs; II between veins. × 160. (K.B.W.)

The *mesophyl* consists of *chlorophyl cells* of the usual type, *fibrovascular bundles* with vessels largely of the single or double spiral type, and branching and anastomosing *latex tubes* accompanying the phloem of the bundles.

The *upper (inner) epiderm* is similar to the lower.

Chief Structural Characters.—Leaves with prominent white midrib and curled or flat divisions.

Epiderm over ribs and veins of elongated cells, jointed hairs, and emergence-like hairs; between ribs and veins of isodiametric wavy-walled cells, jointed hairs, and stomata. Mesophyl with bundles, containing spiral vessels, and accompanying latex tubes.

CHEMICAL COMPOSITION.—Dahlen[1] analyzed both curly (*C. endivia crispa*) and smooth (*C. endivia pallida*) endive, and Agcaoili[2] the smooth (escarole), with the following results:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Dahlen:						
Curly	94.38	2.18	0.13	1.87*	0.61	0.83
Smooth	93.88	1.35	0.13	3.27†	0.63	0.74
Agcaoili:						
Smooth	93.25	1.62	0.23	3.01	0.95	0.94

* Reducing sugars 0.69%. † Reducing sugars 0.83%.

Mineral Constituents.—Richardson,[3] in the dried leaves, found 18.22 per cent of crude ash containing 5.13 per cent of carbon dioxide and 6.07 per cent of sand. The pure ash, calculated free of carbon dioxide and sand, amounted to 16.18 per cent. The analysis of the pure ash follows:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%
37.87	12.12	12.03	1.77	3.37	2.99	5.21	24.62	trace

Minor Mineral Constituents. *Aluminum.*—Leaves 51 mg. per kilo, dry basis (Bertrand and Lévy).[4]

Manganese.—Leaves 35 mg. per kilo, dry basis (Peterson and Skinner).[5]

Zinc.—Outer withered leaves 0.4, inner green leaves 1.9 mg. per kilo, fresh basis (Bertrand and Benzon).[6]

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[1] Landw. Jahrb. 1874, **3**, 723.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] Ann. 1848, **67**, 377.

[4] Bul. soc. hyg. aliment. 1931, **19**, 359.

[5] J. Nutrition 1931, **4**, 419.

[6] Bul. soc. hyg. aliment. 1928, **16**, 457.

CHICORY

Cichorium Intybus L.

Fr. Chicorée. Sp. Achicoria. It. Cicoria. Ger. Cichorie.

The chicory plant when properly bred, grown, and sprouted furnishes two of the choicest of salad vegetables, French endive or witloof (Dutch for white leaf), for which a special strain is preferred, and barbe de capucin (Capuchin beard), for which common or wild chicory may be used.

The roots are dug in the Fall, trimmed, and covered with earth or mulch in a cellar. For the production of barbe de capucin, the narrow shoots are allowed to protrude and are cut from time to time; for French endive the whole is kept well buried until a solid, blanched head is formed. Both forms may be served boiled as well as raw as salad. French endive is produced to some extent in the United States, but the choicest is imported in baskets or boxes from Europe.

MACROSCOPIC STRUCTURE.—French endive, as found in the market, consists only of the inner thoroughly bleached leaves forming a close elongated head. Owing to the immaturity and the forcing, the *leaves* consist chiefly of fleshy midrib with thin leaf tissue forming a narrow margin. The lobing at this stage is indistinct.

MICROSCOPIC STRUCTURE (Fig. 79).—The structure of French endive differs from that of endive in that elongated, straight-walled *epidermal cells* predominate, owing to the prominent midribs, and emergence-like hairs are absent, at least on the edible leaves.

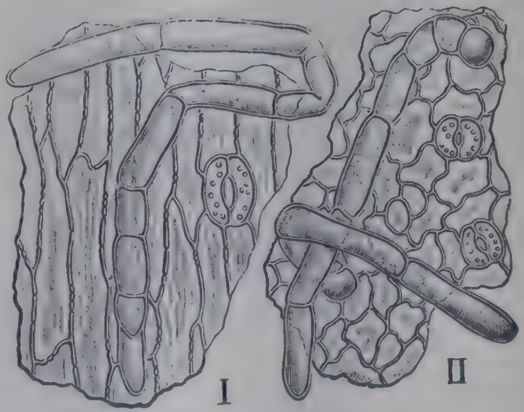

FIG. 79.—Chicory. Lower epiderm of leaf in surface view. I over vein; II between veins. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaves with abnormally large midrib in well-bleached heads.

Structure as in endive, except that elongated epidermal cells predominate and emergence-like hairs are lacking.

CHEMICAL COMPOSITION.—No proximate analyses available.

Minor Mineral Constituents. *Aluminum.*—French endive 22.5, barbe de capucin 10 mg. per kilo, dry basis (Bertrand and Lévy).[1]

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[1] Bul. soc. hyg. aliment. 1931, **19**, 359.

DANDELION

Taraxacum officinale Weber = *T. Dens-leonis* Desf.

Fr. Dent-de-lion. Sp. Diente de león. It. Dente di leone.
Ger. Löwenzahn.

In addition to the common weed introduced into America from the Old World, wild forms of the dandelion occur in northern and Rocky Mountain regions of the United States. Root leaves from meadows are gathered for greens in the Spring at which time they are tender and with little bitter flavor. Cultivated varieties yield leaves of superior texture and flavor which sometimes are blanched by tying like endive.

MACROSCOPIC STRUCTURE.—The elongated, toothed *leaf*, with a prominent midrib, varies from spatulate to pinnately divided and in cultivated varieties is often curled. It is obscurely petioled, the leaf blade gradually narrowing to a margin which usually extends nearly to the base. Long hairs form a felt-like mass at the very base of the leaf and scattered fine hairs occur throughout, especially on the upper side and on the young leaves.

MICROSCOPIC STRUCTURE. Leaf.—Both *epiderms* (Fig. 80) are practically the same in structure except that *hairs* are more numerous on the upper. These are jointed with great variation in the size or length of the joints, the cell at the apex and those immediately beneath often being considerably larger than those farther down. At the base of the leaf, the hairs often reach more than 2 cm. in length. As in other composite leaves, the epidermal cells are elongated with straight walls over the midrib and veins and isodiametric with wavy walls elsewhere. Stomata are numerous. The *mesophyl* contains latex tubes, typical of the family, accompanying the phloem of the fibrovascular bundles. Most of the vessels are of the spiral, often with two strands, or spiral-reticulated types.

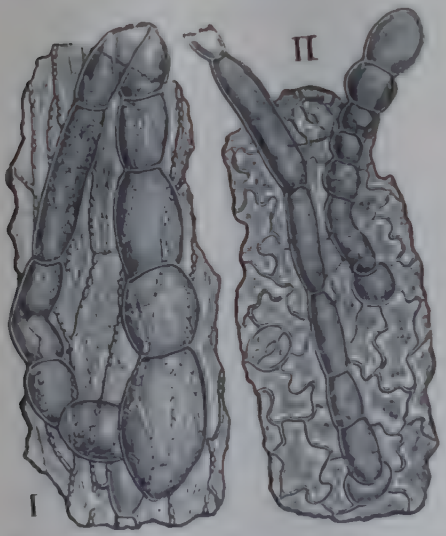

FIG. 80.—Dandelion. Lower epiderm of leaf in surface view. I over vein; II between veins. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—Leaf spatulate to pinnately divided, toothed.

Epiderms with straight-walled, elongated cells over midrib and veins and wavy-walled isodiametric cells between the veins; hairs jointed, often very long. Mesophyl of chlorophyl cells, latex tubes, and fibro-vascular bundles with mostly spiral vessels.

CHEMICAL COMPOSITION.—Following are analyses by Storer and Lewis[1] of an American sample with flower buds and by Chung and Ripperton[2] of an Hawaiian sample, as perfected for the Hawaiian market, where it is known under the Chinese name *pu-kung-ying* and the Japanese name *tampopo*.

Dandelion Greens

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
S. and L.	85.54	2.81	0.69	7.45	1.52	1.99
C. and R.	....	2.40	1.00	10.60	....	....

Mineral Constituents.—Chung and Ripperton[2] found calcium 0.105, iron 0.0027, and phosphorus 0.072 per cent.

Minor Mineral Constituents. *Iron.*—Greens 60.4 mg. per kilo, fresh basis (Peterson and Elvehjem.)[3]

Aluminum.—Greens, wild 135, cultivated (etiolated) 7.4 mg. per kilo, dry basis (Bertrand and Lévy).[4]

Manganese.—Greens 19.2 mg. per kilo, dry basis (Peterson and Skinner).[5]

Copper.—Greens 1.5 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Greens 9.7 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

CARDOON

Cynara Cardunculus L.

Fr. Cardon. Sp. Cardo. It. Girello. Ger. Kardon.

The wild form of cardoon is native about the Mediterranean Sea. It is regarded as the original form of the artichoke and like the latter has thistle-like leaves and flowers. Ordinarily this plant is grown for the fleshy stalks (midrib base) of the root leaves, which are blanched like celery by covering with earth and eaten either as a salad or pot herb. The enlarged root, which differs little from scolymus, is also said to be eaten.

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[1] Bul. Bussey Inst. 1877, p. 117.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Bul. soc. hyg. aliment. 1931, **19**, 359.

[5] J. Nutrition 1931, **4**, 419.

[6] J. Biol. Chem. 1929, **82**, 465.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

MACROSCOPIC STRUCTURE.—There is no distinct petiole, the edible portion being the base of the leaf consisting of a thick midrib, narrow wings, and occasional short lobes. *Leaf blade*, midrib, and veins are covered with a dense felt of hairs which give both surfaces a green-gray or nearly white appearance. The leaf is deeply cleft or parted, and the divisions are variously lobed or toothed with a spine at the end of each division.

MICROSCOPIC STRUCTURE.—Cross sections of the midrib base show *outer* and *inner epiderms*, a mass of *collenchyma* tissue below the outer epiderm, and a bulky *mesophyl* with one large and several small fibro-vascular bundles forming the inner tissues. Both *epiderms* are much the same in structure and bear two skinds of *hairs*: (1) much-elongated, flattened, twisted unicellular or jointed with only one or two short basal cells and a very long terminal cell; (2) capitate, with very short stalk, the cells of both stalk and head being in two rows. Each *fibro-vascular bundle* has a mass of bast fibers on both phloem and xylem sides, and the whole is surrounded by a row of starch cells. The *spines* have greatly elongated, thick-walled, porous epidermal cells, resembling bast fibers, which contribute to their rigidity. A narrow vascular bundle runs into each spine.

Chief Structural Characters.—Leaf deeply cleft or parted, spiny, densely hairy on both sides; base of midrib thick, edible.

Epiderms with (1) much elongated, jointed hairs with long end cell and (2) short capitate hairs with double row of cells; collenchyma on outer side and bast fibers on both sides of fibro-vascular bundles, the whole surrounded by starch cells.

CHEMICAL COMPOSITION.—Analyses of 3 varieties, given by Peano,[1] are not available.

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[1] Ann. accad. agr. Torino, 1909, **52**, 97.

FLOWER VEGETABLES

FLOWERS are less often used as food than other parts of plants. It is true that certain pot greens may be in flower when gathered, but usually the flowers do not appear until after the stem has become too tough for cooking.

Squash flowers are in evidence in Italian markets. Certain flowers, such as those of the lilies eaten by the Chinese and the garden nasturtium serve as relishes. Cauliflower, including broccoli, and artichoke lead among flower vegetables.

RELATION OF FLOWERS TO LEAVES.—Vegetables consisting essentially of inflorescence, whether normal, such as squash flowers and lilies or botanical monstrosities, such as cauliflower and broccoli, are logically treated immediately after leaf and stem vegetables since the flower is morphologically a modified leaf.

One unfamiliar with botanical literature is entitled to a few words of explanation. Of the four primary parts of the flower, the calyx is often leaf-like and the corolla in some flowers differs little from the calyx, although ordinarily characterized by its delicate texture and varied coloring. The pistil may be visualized as a leaf rolled up on its longitudinal axis with ovules on the placenta formed by the united margins. An explanation of the relation of stamens to leaves involves greater detail and need not here be attempted.

CHEMICAL CONSTITUENTS.—The green parts of flowers doubtless contain constituents similar to those of leaves of the same plant. Other parts have been little studied except as regards their odorous constituents, such as oil of rose, or their color principles which are classed as *anthocyanins* or in other groups. The stigmas of saffron yield *crocin*, a glucosidal dye, as well as essential oil. These together with cloves, cassia buds, and capers, which are flower buds, are described under Spices in Volume III. As the reproductive processes center in the anthers and ovaries, these are rich in vital elements, but ordinarily only bees that collect the pollen and insects that prey on the ovules profit thereby. In cauliflower *mannite*, *pentosans*, and *methyl pentoses* have been identified. The *inulin* and *latex* of the artichoke are also of interest.

FLOWERS OF THE LILY FAMILY

(*Liliaceæ*)

The tawny lily is the only member of the family furnishing a flower vegetable here described.

TAWNY LILY

Hemerocallis fulva L.

Chin. Kam-cham-t'soi.

In the United States this lily is often found in old flower gardens or escaped by the roadside, having been introduced from Europe in Colonial days. The flower is regarded by the Chinese as a delicacy.

MACROSCOPIC STRUCTURE.—The *flowers* are of the usual lily type and need not be described beyond stating that the yellow color at the base of the perianth limbs passes into purplish orange and brick color at the center and tip, the darker color being largely in the nerves.

MICROSCOPIC STRUCTURE. Perianth.—The tissues are (1) *lower (outer) epiderm* of isodiametric cells, passing into longitudinally elongated cells over the veins and toward the base, (2) *spongy mesophyl* containing latex tubes and small grains of transitory starch near the bundles, and (3) *upper (inner) epiderm* of cells similar to those of the lower epiderm but with the usual papillæ characteristic of floral envelopes. The yellow *color* of the petals is due to needle-shaped chromoplasts; the red and purple color is in solution in the upper epiderm.

Pistil.—The elongated cells of the style pass into the typical papillose tissue of the stigma.

Stamens.—Large stomata occur on the epiderm of the *anthers*. Spirally reticulated cells, characteristic of the endothecium, are also present. The *pollen grains* are oval, smooth, up to 128 μ long, with knobby thickenings on the wall.

CHIEF STRUCTURAL CHARACTERS.—Flower yellow, in parts brick color.

Upper epiderm of perianth with papillæ. Pollen grains oval, up to 128 μ long, smooth, with knobby thickenings on wall.

CHEMICAL COMPOSITION.—Tabulated below are an analysis of the fresh flowers from China by Sherman and Wang,[1] of the dried flowers from San Francisco by Blasdale,[2] and of Kinmchan, made from the flowers in Formosa, by Okumura:[3]

COMPOSITION OF TAWNY LILY

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
S. and W.:									
Fresh flowers	85.49	1.66	0.40	10.44	....	......	......	1.23	0.78
Blasdale:									
Dried flowers	15.70	10.11	3.42	58.39	12.40	30.51	5.98	8.74	3.64
Okumura:									
Kinmchan...	22.98	9.93	1.93	53.83	11.82	11.90	......	5.32	6.01

Nitrogenous Bases.—Okumura[3] isolated from 2 kilos of Kinmchan: 0.14 gram of *adenine* as picric acid salt, 0.50 gram of *choline* as platinum salt, and a trace of *arginine*.

Mineral Constituents.—Okumura[3] found in the ash of Kinmchan:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
40.79	2.74	8.56	5.22	1.52	1.32	5.70	3.76	12.67	1.85

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[1] Philippine J. Sci. 1929, **38**, 69.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[3] J. Tokyo Chem. Soc. 1920, **41**, 556.

FLOWERS OF THE MUSTARD FAMILY

(*Cruciferæ*)

CAULIFLOWER and broccoli represent the group.

CAULIFLOWER

Brassica oleracea L. var. *botrytis* DC.

Fr. Chou fleur. Sp. Coliflor. It. Cavolo fiore. Ger. Blumenkohl.

This vegetable, a botanical monstrosity, is perhaps the most highly esteemed member of the family. Broccoli is a sub-variety of slower development. Cauliflower is most commonly eaten as a pot vegetable. It is also pickled, being one of the vegetables often present in mixed pickles.

MACROSCOPIC STRUCTURE.—By abortion of the *flower head*, there is formed a white mass of " curd " which is encircled by inedible green leaves. In the ideal head the *leaves* separating the primary sections are white and inconspicuous. The primary sections in like manner are divided into secondary, and so on, the ultimate groups consisting of minute, rounded, abortive flower buds surrounded by minute, blunt or club-shaped leaves (Fig. 81).

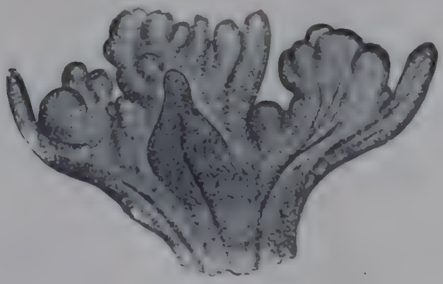

FIG. 81.

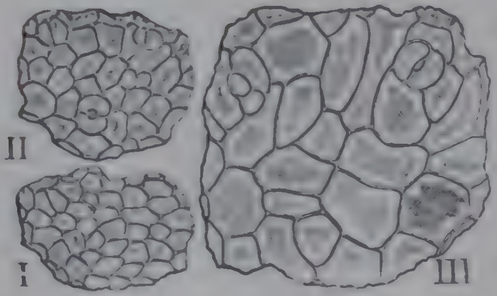

FIG. 82.

FIG. 81.—Cauliflower. Portion of head showing ultimate divisions into flower buds and leaves. × 30. (K.B.W.)

FIG. 82.—Cauliflower. I epiderm of flower bud; II lower epiderm of medium sized colorless leaf among flowers; III epiderm of stem in head. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE. Stem.—Under this head are included the stem, pedicles, and peduncles. The elements are (1) *epiderm* (Fig. 82, III) which in the smaller stems consists only of large isodiametric cells but in the larger stems shows differentiation into ground cells and stomata, (2) *cortex* of characterless, small, isodiametric cells, (3) a ring of *fibro-vascular bundles* with numerous spiral vessels and occasional reticulated and pitted forms, and (4) a bulky *pith* of small isodiametric cells. Accompanying the fibro-vascular bundles of the larger stems are thick-walled, porous cells.

Leaf.—The cells of the *epiderm* on the smallest rudimentary leaves are small, isodiametric, of uniform character; those on the larger leaves (Fig. 82, II) belong in part to stomata. Over the veins the cells are elongated. The vessels of the fibro-vascular bundles are largely spiral.

Flower.—The cells throughout are small, thin-walled, and characterless. Stomata are absent on the *epiderm* (Fig. 82, I), and the vessels of the rudimentary *fibro-vascular bundles* are of the spiral type.

CHIEF STRUCTURAL CHARACTERS.—Edible part of white, curd-like mass consisting of abortive inflorescence.

Epiderm of larger stems and leaves with stomata, cells of stem large; epiderm of flowers of small cells without stomata. Vessels largely spiral.

CHEMICAL COMPOSITION.—Analyses of cauliflower reported by Collier,[1] Atwater and Bryant,[2] and v. Schleinitz[3] follow:

COMPOSITION OF CAULIFLOWER

	Water	Protein	Protein, pure	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
Collier........	90.82	1.62	....	0.79	4.94	1.02	0.81
A. and B......	93.8	2.0	....	0.20	3.4		0.6
v. Schleinitz...	90.68	3.11	1.70	0.40	3.73	1.15	0.93

Carbohydrates.—Wittmann[4] found 1.00 per cent of *pentosans* in cauliflower. Dmochowski and Tollens[5] state that, in addition to *cellulose, pentosans*, and *methylpentosans, dextrose* and *levulose* are present. Busolt[6] was unable to find dextrose but succeeded in isolating *mannite* in crystalline form.

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[1] U. S. Dept. Agr. Rep. 1881–82, p. 555.

[2] One of the two analyses in their Compilation, the other being by the foregoing author.

[3] Landw. Jahrb. 1918, **52,** 131.

[4] Z. landw. Vers. Oesterr. 1901, **4,** 131.

[5] J. Landw. 1910, **58,** 27.

[6] Ibid. 1913, **61,** 153.

Mineral Constituents.—Analyses by Wolff[1] of the ash of cauliflower and by Nelson and Mottern[2] of the ash of broccoli, expressed in both cases in percentages of the green vegetable, follow:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3*	Mn_3O_4	P_2O_5	SO_3	SiO_2	Cl	Sand
	%	%	%	%	%	%	%	%	%	%	%
Cauliflower.	0.36	0.05	0.05	0.03	......	......	0.16	0.10	0.03	0.03	.....
Broccoli:											
Buds.....	0.30	.....	0.30	0.02	0.012	0.006	0.17	.....	.....	.....	0.03
Leaves...	0.34	.....	0.38	0.16	0.026	0.005	0.12	.....	.....	.....	0.06

* Includes Al_2O_3.

Minor Mineral Constituents. *Iron.*—Head 14.3 mg. per kilo, fresh basis (Peterson and Elvehjem).[3] Head, 2 samples, 9.5, 10.9 mg. per kilo, fresh basis (Toscani and Reznikoff).[4]

Manganese.—Head 25.2 mg. per kilo, dry basis (Peterson and Skinner).[5]

Copper.—Head 2.0 mg. per kilo, fresh basis (Guérithault).[6] Head 1.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

Zinc.—White head cauliflower 2.3 mg. per kilo, fresh basis (Bertrand and Benzon).[8]

BROCCOLI

This vegetable, long popular in Italy, has recently come into prominence in the United States. It may be described as cauliflower in small heads with inflorescence of a green color.

MACROSCOPIC STRUCTURE.—The flower buds, which in cauliflower are abortive, are here more or less perfect. Occasionally small, perfectly developed flowers with 4 green sepals, 4 yellow petals, 6 stamens, and 1 pistil are present.

MICROSCOPIC STRUCTURE.—The tissues are characterless excepting the *pollen grains* which are spherical, with three lobes, up to 15 μ in diameter.

CHEMICAL COMPOSITION.—Nelson and Mottern[9] analyzed separately the buds (abortive flowers) and leaves of broccoli with results as shown below. The stems contained 90.9 per cent of moisture but were not analyzed with respect to other constituents.

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[1] Aschenanalyzen.

[2] J. Am. Chem. Soc. 1931, **53**, 1909.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Nutrition 1934, **7**, 79.

[5] J. Nutrition 1931, **4**, 419.

[6] Bul. soc. hyg. aliment. 1927, **15**, 386.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

[9] J. Am. Chem. Soc. 1931, **53**, 1909.

Composition of Broccoli (Nelson and Mottern)

	Water	Protein	Nitrates as KNO_3	Fat	Invert sugar	Sucrose	Starch	Pentosans	Fiber	Ash, total	Ash,* alk.
	%	%	%	%	%	%	%	%	%	%	cc.
Buds...	88.1	4.39	0.09	0.74	trace	0.00	1.30	0.91	1.42	1.69	93
Leaves.	88.3	4.04	0.12	0.84	......	.....	......	......	1.11	2.41	144

* Cc. $N/10$ acid per 100 grams material.

Acids.—According to Nelson and Mottern,[1] *citric acid* is the predominating acid of broccoli. In both the buds and the leaves they found 0.02 per cent of *oxalic acid* and a small amount of *succinic acid.* They also found *l-malic acid,* the ratio to citric acid being about 2 : 3.

Mineral Constituents.—See Cauliflower.

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[1] Loc. cit.

FLOWERS OF THE COMPOSITE FAMILY

(*Compositæ*)

THE family is represented by the artichoke.

ARTICHOKE

Cynara Scolymus L.

Fr. Artichaut. Sp. Alcachofa. It. Carciofo. Ger. Artischoke.

There is abundant evidence that the artichoke is a form of cardoon (which see) derived by cultivation. It is extensively grown in the Mediterranean region, also in California and Florida.

MACROSCOPIC STRUCTURE.—Only the thickened lower part of the involucral scales and the receptacle (heart) of the thistle-like flower, gathered before blossoming, are eaten. The *involucral scales* are greenish or purplish with a short, sharp spine arising from the notched apex. In eating, the tender mesophyl is torn away from the outer tough tissues. The *receptacle* is soft and tender throughout, forming a cushion-like mass.

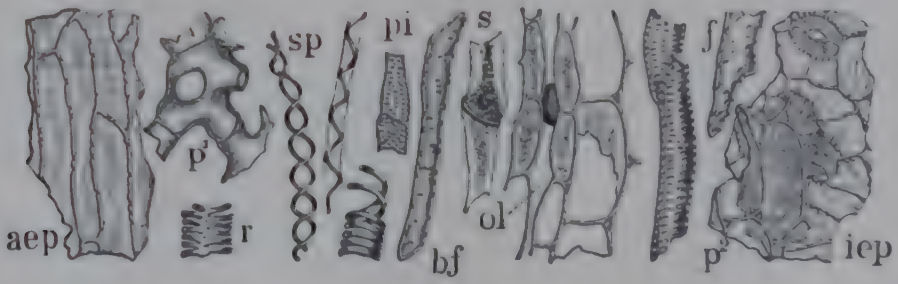

FIG. 83.—Artichoke. Elements of base of involucral scale. *iep* outer epiderm; *aep* inner epiderm; p^2 hypoderm; *f* element from fiber layer; p^1 spongy parenchyma of mesophyl; *sp* spiral, *r* reticulated, and *pi* pitted vessels of xylem; *bf* bast fiber; *s* sieve tube; *ol* oleoresin cavity flanked by secreting cells. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE.—*Inulin* is abundant throughout.

Involucre (Fig. 83).—The scales consist of six layers but the tissues of the fourth, classed as mesophyl, vary greatly in character according to the position: (1) *outer* (*lower*) *epiderm* (*iep*) of isodiametric or elongated, irregularly arranged, striated, beaded cells and stomata; (2) *hypoderm* (p^2) of about five rows of longitudinally elongated cells; (3) *fiber layer* (*f*) consisting of longitudinally arranged fibers in about fifteen rows; (4) *mesophyl* with fibro-vascular bundles, oleoresin cavities, and latex tubes in a ground tissue varying from rounded cells to spongy parenchyma (p^1) and then to chains of small cells about large intercellular spaces; (5) *collenchyma*, several cells thick; and (6) *inner epiderm* (*aep*), toward the apex similar to the outer epiderm but at the base mostly of elongated cells.

Running through the outer mesophyl are the *bundles* with vessels of various types (*sp*, *pi*, *r*). Of chief interest are the schizogenous *oleoresin cavities* (*ol*), containing minute brown drops, each surrounded by small secretion cells, and the numerous *latex tubes*, consisting of elongated cells which neither branch nor anastomose, with granular contents.

The *spines* consist of a vascular bundle with narrow elements surrounded by broad fibers with broad lumens, the whole enclosed in an epidermal tissue of elongated elements.

Receptacle.—The *ground tissue* throughout consists of rounded cells with intercellular spaces. Through this run *vascular bundles*.

CHIEF STRUCTURAL CHARACTERS.—Scales thickened at base with spine in notch at end. Receptacle much thickened.

Mesophyl with oleoresin cavities and many elongated latex tubes. Receptacle with ground tissue of rounded cells in loose contact. Inulin abundant.

CHEMICAL COMPOSITION.—Analyses of the whole head give little idea of its nutritive value, since much is rejected on eating. The heart is eaten entire. Results on the whole head by Okey and Williams[1] and on canned hearts by McElroy and Bigelow[2] follow:

COMPOSITION OF ARTICHOKES

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Salt
	%	%	%	%	%	%	%
Whole, fresh							
American....	85.5	2.8	1.4	6.8*	2.4	1.1	....
Hearts, canned							
French......	90.21	0.77	0.02	6.17	0.60	2.23	1.80
French......	93.31	0.53	0.01	4.01	0.61	1.53	1.07
American....	93.85	0.98	0.02	3.22	0.53	1.40	0.95

* Reducing sugars 0.6, inulin 2.5, and insoluble carbohydrates 0.6%.

Inulin appears to make up more than one-third of the nitrogen-free extract of the whole head. No data on the proportion of inulin in the heart are available.

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[1] J. Am. Chem. Soc. 1920, **42**, 1693.

[2] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, 1128.

Minor Mineral Constituents. *Iron.*—Head 18.9 mg. per kilo, fresh basis (Peterson and Elvehjem).[1]

Manganese.—Edible portion 14.25 mg. per kilo, dry basis (Quartaroli).[2] Head 23.2 mg. per kilo, dry basis (Peterson and Skinner).[3]

Copper.—Edible portion 4.62 mg. per kilo, dry basis (Quartaroli).[2] Head 3.1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

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[1] J. Biol. Chem. 1928, **78**, 215.

[2] Ann. chim. appl. 1928, **18**, 47.

[3] J. Nutrition 1931, **4**, 419.

[4] J. Biol. Chem. 1929, **82**, 465.

FRUIT AND SEED VEGETABLES

FRUIT vegetables, although containing seeds, are valuable chiefly for the fleshy pericarp tissues which may be more or less distinctly saccharine and (or) acid (melons, tomato) or bland and inert (string bean, pumpkin, squash, okra). *Seed vegetables* are represented by sweet corn, which strictly speaking is a fruit with a thin pericarp, and numerous species of legumes.

PERICARP.—Since fruit vegetables, like fruits in the popular sense, are valued chiefly for the fruit flesh, the general consideration of the pericarp is reserved for Part II of this Volume.

SEED.—Excepting the cereals, leguminous seeds green and dry, notably peas and beans, are more valuable as human foods than seeds of any other family and perhaps than all other seeds taken together. In the United States, however, sweet corn in the succulent stage vies with green peas and beans as a seed vegetable.

Classification of Seeds Based on Composition.—Although all seeds show on analysis nitrogen-free extract, fat, and fiber, the nature of the individual constituents of the three groups and their proportion differ widely.

Starch is deposited as reserve material in large amounts in certain seeds but is entirely absent in others. Oil is the chief constituent of many starch-free seeds. In a relatively few seeds reserve material accumulates in the cell walls as polysaccharides, known collectively as hemicellulose, hydrolyzable with acid to sugars. Most seeds accordingly belong in three well-marked groups based on the chief constituent of each: (1) *starch seeds* (e.g., peas, beans, sweet corn), (2) *oil seeds* (e.g., soy bean), and (3) *hemicellulose seeds* (e.g., carob, tamarind). The examples given, with the exception of sweet corn, are of species of legumes; numerous other species of starch and oil seeds are described in this Volume under legumes and in Volume I.

The reserve material may be largely in the embryo (e.g., peas, beans, tamarind), largely in the endosperm (e.g., sweet corn, carob), or partly in one and partly in the other. In pepper, but not in the seed of any common vegetable or fruit, it is in the perisperm.

FRUITS OF THE GRASS FAMILY

(*Gramineæ*)

Only one of our cereals, sweet corn, is grown as a garden vegetable Doubtless the immature grain of other cereals would be suitable for human food were it possible to readily remove the closely enveloping chaff.

SWEET CORN

Zea Mays L. var. *saccharata* Sturt.

Fr. Maïs sucré. Sp. Maíz. Ger. Zuckermais.

Mature sweet corn is described under Cereals, Volume I.

Field corn was grown as a vegetable before the introduction of improved varieties of sweet corn. According to Sturtevant, sweet corn was cultivated as early as 1779 at Plymouth, Mass., the seed having been obtained from the Susquehanna Indians. Numerous varieties, differing greatly in the color, shape, and size of the kernels, have been developed since the middle of the nineteenth century.

Being a favorite vegetable in the United States, it is grown in enormous quantities both in private and market gardens and as a field crop for canning.

MACROSCOPIC STRUCTURE.—Green corn is eaten while still "in the milk," that is, when the contents of the endosperm are succulent and milky from suspended starch grains. The kernels are well rounded even when of full size; it is only on drying and shrinking that wrinkles appear on the surface. However carefully husked, shreds of the inner husk, entangled between the kernels, and of the silk remain on ear; these as well as fragments of the chaff are removed with the kernels in cutting from the cob.

MICROSCOPIC STRUCTURE. Fruit.—See also Sweet Corn, Volume I. The *starch grains* continue to develop after the cell walls have reached their full development. The milk squeezed from a kernel shows the starch granules suspended in the cell liquid, the smallest showing lively Brownian movements. Some of the round or somewhat polygonal grains are 15 μ or more in diameter and show distinct polarization crosses. Most of the granules are small, and many of them are in aggregates of from two to many individuals. These aggregates are isodiametric, rod-shaped, or even branching, presenting a variety of forms.

At all edible stages, iodine in potassium iodide imparts a deep coffee-brown color to the liquid portion of the mount, showing that the *soluble carbohydrate*, which distinguishes mature sweet corn from dent, flint, and pop varieties, is not due to solution of the mature starch grains, such as occurs during sprouting, but is formed before the starch grains reach any considerable size.

Silk.—The conspicuous elements are (1) *epiderm* of elongated cells, with parallel sides arranged end to end, and hairs up to 1 mm. long, and (2) *fibro-vascular bundle zone.*

The *hairs* are either (1) simple jointed, that is made up of several cells placed end to end in a row, or (2) compound jointed, that is, two or three, seldom more, cells broad, the number diminishing toward the apex, as well as two or more cells long. The compound jointed hairs are best described as consisting of several jointed hairs united side by side, those in the middle being longest and having the most joints, the rounded tip of each component hair often being free from its neighbor. The *vessels* of the bundle zone are mostly spiral or annular.

Husk.—The edge of the inner husk leaves, which are trapped between the rows of kernels, consists chiefly of the *outer epiderm* with deeply wavy walls, stomata, and numerous hairs and the *inner epiderm* with beaded, straight-walled cells, stomata, and some hairs. These tissues have their counterparts in the chaff.

Chief Structural Characters.—Cell walls as in mature sweet corn; starch in simple, mostly rounded grains from minute to 15 μ or in isodiametric or rod-shaped aggregates; liquid portion of milk giving a coffee-brown color with iodine.

CHEMICAL COMPOSITION.—Analyses of mature sweet corn are given under Dent Maize, Volume I.

The composition of sweet corn is shown in the table on the next page. The average of analyses of canned corn compiled by Atwater and Bryant[1] includes those of McElroy and Bigelow.[2]

Influence of Environment on Composition.—Straughn and Church[3] carried out experiments with 2 varieties, Crosby and Stowell's Evergreen, during 4 successive years in 6 Atlantic states. A summary of average results on total sugars, obtained by copper reduction after inversion, and on moisture appears in the second table:

---

[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, 1126.

[3] U. S. Dept. Agr., Bur. Chem. 1909, Bul. **127**.

COMPOSITION OF SWEET CORN, FRESH AND CANNED

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Salt
		%	%	%	%	%	%	%
Sweet corn, fresh:								
A. and B.	3							
Min.	......	72.1	2.8	1.0	14.1*	......	0.7	......
Max.	......	81.3	3.7	1.1	22.6*	......	0.8	......
Aver.	......	**75.4**	**3.1**	**1.1**	**19.7***	**0.5†**	**0.7**	......
Sweet corn, canned:								
McE. and B.:	42							
Min.	......	68.32	1.97	0.66	11.69	0.41	0.41‡	0.01
Max.	......	83.67	3.73	1.89	25.09	1.24	0.80‡	0.92
A. and B.:	52							
Aver.	......	**76.1**	**2.8**	**1.2**	**19.0***	**0.8§**	**0.9**	......

* Includes fiber. † 1 sample. ‡ Salt-free. § 43 samples.

AVERAGE WATER AND SUGAR CONTENT OF SWEET CORN (STRAUGHN AND CHURCH)

	Water				Total Sugars			
	1905	1906	1907	1908	1905	1906	1907	1908
	%	%	%	%	%	%	%	%
Crosby:								
Florida	......	67.11	72.11	67.89	......	5.01	5.57	4.99
South Carolina	65.84	76.77	74.27	76.72	12.22	4.73	7.25	5.19
Maryland	......	69.79	75.14	......	......	5.01	5.40	......
Connecticut	73.01	65.26	71.19	70.12	7.73	4.23	4.83	4.76
Maine	79.30	71.88	......	73.72	6.50	5.66	......	4.66
Stowell's Evergreen:								
Florida	......	70.27	77.08	76.24	......	4.07	5.43	4.59
South Carolina	75.54	71.72	76.82	75.50	6.68	4.99	4.95	4.41
Maryland	78.13	72.34	80.59	77.92	5.78	3.77	4.83	5.20
New Jersey	69.28	......	......	......	4.26	......	......	......
Connecticut	74.62	73.38	78.20	70.91	5.36	3.92	3.69	2.92

Wiley, in commenting on the above results, notes that during the four years the average sugar content is higher in the southern than in the northern grown corn but this greater sweetness is offset by inferior physical characters, the northern grown corn being more tender and edible for a longer period. He considers the amount and distribution of rainfall to be the most important factor affecting quality, an excess as well as a deficiency being alike injurious. The content of sugars does not appear to depend so much on temperature and length of day as in the case of the sugar beet.

Relation of Season and Maturity to Composition.—In experiments by Culpepper and Magoon[1] the percentage of total sugars increased for about 15 days after formation of the silk, then decreased. At the start the reducing sugars were high and the non-reducing sugars (largely sucrose) were low, but soon the order was reversed. Both total and soluble polysaccharides increased throughout development, the latter being present in much larger amount than in field corn.

Magoon and Culpepper[2] continued the experiments with two varieties planted at intervals. The results obtained with the Golden Bantam corn for three of the plantings appear below. The total solids in the three series increased respectively as follows: 10.62 to 41.58, 13.41 to 41.22, and 9.56 to 34.95 per cent. They concluded that temperature was the most important seasonal factor affecting the corn for canning, and that rainfall, although markedly affecting vegetative activity, had no significant influence.

CARBOHYDRATES IN SWEET CORN SHOWING SEASONAL VARIATION (MAGOON AND CULPEPPER)

Days after silking	Planted April 28				Planted June 7				Planted July 28			
	Sugars *		Polysaccharides		Sugars *		Polysaccharides		Sugars *		Polysaccharides	
	Reducing	Non-red.	Total †	Sol.‡	Reducing	Non-red.	Total †	Sol.‡	Reducing	Non-red.	Total †	Sol.‡
	%	%	%	%	%	%	%	%	%	%	%	%
5	3.36	1.21	1.68	0.06	3.80	1.16	2.42	0.13	3.30	0.96	1.65	0.05
10	3.91	1.65	1.88	0.15	3.68	1.76	2.40	0.40	3.25	0.87	1.76	0.10
15	2.28	4.56	7.97	3.32	1.84	4.44	7.98	3.32	3.31	1.23	1.79	0.08
20	1.25	3.63	17.79	8.68	1.12	3.86	16.61	8.08	3.45	1.96	2.26	0.75
25	0.66	2.48	26.19	12.93	0.81	2.83	22.17	10.96	2.66	4.27	4.59	1.89
30	0.59	1.47	30.58	15.83	0.70	2.26	29.60	13.92	2.19	4.35	8.14	3.01
35	......	......	......	......	......	......	......	......	1.85	4.16	11.42	5.57
40	......	......	......	......	......	......	......	......	1.26	3.24	15.92	7.49
50	......	......	......	......	......	......	......	......	0.97	2.15	20.37	10.07
60	......	......	......	......	......	......	......	......	0.98	1.60	24.77	11.60

* As invert. † As starch. ‡ As dextrin.

Changes in Composition during Storage; Respiration.—In experiments on the rate of deterioration of sweet corn after picking, Appleman and Arthur[3] found that the loss of sugar was rapid at first then slackened until about 18 per cent of the total sugars and 30 per cent of the sucrose remained. An increase of 10° C. doubled the rate up to 40°, when the rate decreased. The decrease of sugar was largely explained by an increase in starch. The loss of carbon dioxide through respiration during 24 hours at 30° corresponded to a loss of only 3.2 pounds of sugar per ton or 0.13 per cent.

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[1] J. Agr. Res. 1924, **28**, 403.

[2] Ibid. 1926, **33**, 1043.

[3] J. Agr. Res. 1919, **17**, 137.

Appleman[1] found that the catalase activity of the juice of sweet corn as well as of potatoes is an index of the rate of respiration, which is high when the corn is just picked.

Enzymes.—See Respiration above.

Minor Mineral Constituents. *Iron.*—Kernels, dried 29 mg. per kilo (Sherman).[2] Sweet corn, 2 samples, 5.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Aluminum.—Sweet corn 2.6 mg. per kilo, fresh basis (Underhill, Peterman Gross, and Krause).[4]

Manganese.—Sweet corn 4.7 mg. per kilo, dry basis (Peterson and Skinner).[5]

Copper.—Evergreen 1.1, Golden Bantam 0.6 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

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[1] Am. J. Bot. 1918, **5**, 207.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Am. J. Physiol. 1929, **90**, 172.

[5] J. Nutrition 1931, **4**, 419.

[6] J. Biol. Chem. 1929, **82**, 465.

FRUITS AND SEEDS OF THE PEA FAMILY

(*Leguminosæ*)

Classification of Food Legumes.—Following is a list of the genera by sub-families and tribes. Unless otherwise stated, the seed or whole pod is edible.

Mimosaceæ.

- I. *Ingeæ.* *Pithecolobium* (kamanchile [1]).

Papilionaceæ.

- II. *Genisteæ.* *Lupinus* (blue, yellow, and white lupines [2]).
- III. *Sophoreæ.* *Castanospermum* (bean tree).
- IV. *Hedysareæ.* *Arachis* (peanut), *Ornithopus* (serradella [3]), *Onobrychis* (sainfoin [3]), *Lespedeza* (Japan clover [3]).
- V. *Dalbergieæ.* *Coumarouna* (tonka bean).
- VI. *Loteæ.* *Lotus* (bird's foot clover [3]).
- VII. *Vicieæ.* *Ervum* (lentil [2]), *Vicia* (broad bean, vetches [2]), *Pisum* (pea [2]), *Cicer* (chick pea [2]), *Lathyrus* (chickling vetch,[2] vetchling,[4] Spanish lentil [2]).
- VIII. *Phaseoleæ.* *Phaseolus* (common bean, scarlet runner, Dutch case-knife bean, lima bean, adzuki), *Vigna* (China bean [2]), *Dolichos* (hyacinth bean), *Canavalia* (Jack bean), *Glycine* (soy bean [2]), *Stizolobium* (velvet bean), *Pachyrrhizus* (yam bean [4]), *Pueraria* (kudzu [4]), *Apios* (ground nut [4]).
- IX. *Trifolieæ.* *Trifolium* (clovers [3]), *Medicago* (alfalfa [3]), *Trigonella* (fenugreek).
- X. *Galegeæ.* *Astragalus* (coffee astragalus).

Cæsalpiniaceæ.

- XI. *Amherstieæ.* *Tamarindus* (tamarind).
- XII. *Cassieæ.* *Cassia* (coffee cassia), *Ceratonia* (carob).

COMPARATIVE MACROSCOPIC STRUCTURE. Pericarp.—Usually the pod is elongated, sometimes also spiral, and has both dorsal and ventral sutures, the seeds being borne along the latter; the tamarind (Fig. 230), however, has no evident sutures. The pod may or may not be septate, but in either case has a well-developed parchment-like layer adjoining or toward the endocarp.

Seed.—In *Papilionaceæ* the seed is usually amphitropous, in *Mimosaceæ* and *Cæsalpiniaceæ* anatropous. In general it is characterized by (1) the thin *spermoderm*; (2) the distinct oval *hilum* or scar (Fig. 99, *H*) where the seed separates from the *funiculus*; (3) two small humps adjoining one end of the hilum forming the heart-shaped *strophiole* (*S*);

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[1] Aril edible. [2] Used also for forage. [3] Used only for forage. [4] Root-tuber edible.

(4) the *raphe* (*R*) (absent in *Cæsalpiniaceæ*) forming a more or less distinct ridge from the strophiole to (5) the usually indistinct *chalaza*; (6) the *micropyle* (*M*) near the hilum on the opposite end from the strophiole, the opening through which the pollen tube entered in fertilization; (7) the thin (garden legumes) rather thick (clover group) or bulky (carob and coffee cassia) *endosperm*; (8) the usually bulky *cotyledons*; and (9) the small *radicle*, the form often showing through the spermoderm.

The *spermodern*, often together with remnants of the endosperm, forms a skin which is thickest beneath the hilum and may extend into the reentrant angles on both sides of the radicle. A dull spot occurs on the sides of the seeds of carob and coffee cassia.

The more or less elongated *hilum* in the *Papilionaceæ* has a slit running through the longest diameter. In the kidney-shaped seeds of the bean group (Fig. 99) the hilum is in the reentrant curve, in the tonka bean it is on the outward curve, in the lupines (Figs. 84, 85, and 87) it is on an elevation, in the broad bean (Fig. 90) it is at one end, in the pea (Fig. 94), which is globular, it is near the end of the radicle. In the *Cæsalpiniaceæ* the hilum is inconspicuous.

A *caruncle* is strongly developed in the hyacinth and velvet beans, forming a raised border of the hilum; in other legumes here described it is less conspicuous or lacking.

The edible portion of kamanchile is the fleshy *aril* which completely envelops the seed.

Hilum cushion is a term used for the spongy tissues, broken away from the funiculus, covering the hilum of certain legumes.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—Kraus[1] observed that the pod of the *Papilionaceæ* belongs to the type with an outer mesocarp of isodiametric cells and an inner mesocarp of sclerenchyma fibers.

Epicarp.—In addition to epidermal cells of the common type and stomata, hairs are present in certain species. In the string bean (Fig. 100) the hairs are hooked, in the peanut (Vol. I, Fig. 212) of the root type, in the Jack bean partly jointed and warty and partly capitate.

Hypoderm.—The cells are tangentially elongated.

Mesocarp.—During the succulent period, transitory starch is present, also chlorophyl, except in wax beans. In the carob remarkable bodies (Fig. 234), the "Inklusen" of Tichomirow, reacting like tannins, and in the tamarind tartrate crystals (Fig. 231) are characteristic.

Crystal Layer.—Single crystals of calcium oxalate occur in cells accompanying the vascular bundles of the garden legumes (Fig. 100). In the edible-podded pea such cells form a layer adjoining the inner mesocarp.

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[1] J. wiss. Bot. 1866-7, **5**, 83.

Fiber Layer.—Diagonally arranged sclerenchyma fibers (Fig. 100) form a layer in garden legumes. In the peanut the layer (Vol. I, Fig. 213) is strongly developed.

Inner Parenchyma.—The tissues differ with the species. Crystal cells are numerous in most legumes.

Endocarp.—In the string bean the cells are polygonal; in the edible-podded pea they form papillæ, in the carob and tamarind they are thick-walled.

Spermoderm.—The literature is particularly rich.[1]

Palisade Layer.—The outer epiderm (*pal* in following figures), or Malpighian layer, consists of palisade cells with height (excepting the peanut Vol. I, Fig. 214, *aep*) greatly exceeding breadth. In the chick pea (Fig. 98), they show great variation in height. The upper end may be flat or rounded. In fenugreek (Vol. III) the wall proper, exclusive of cuticle, is pointed, in alfalfa (Vol. I, Fig. 270) rounded.

Commonly at the inner end the walls are thin and the lumen broad, but in the outer portion the walls are thick and the lumen narrow, often reduced to a mere line. In tamarind (Fig. 232) and coffee cassia the lumen has two bulbous enlargements. The thickening of the walls is due to strips arranged about the lumen like the segments of an orange about the core. Tschirch and Oesterle[2] state that the strips are twisted spirally. In lupines (Fig. 86) the walls are geniculate; in bean tree seed, exclusive of cuticle, thin throughout; in chick pea (Fig. 98), thin except at the two ends. Chlorzinc iodine stains the walls brick red.

A light line (*l* in cuts showing cross sections), is always present; more than one line occurs in some species. At the hilum, with few exceptions, the palisade layer is double (Fig. 114).

Subepiderm.—The cells (*sub* in following figures) are either (1) more or less spool-, hourglass-, column-, or bone-shaped, often with distinct ribs, and inconspicuous contents (Fig. 86); or (2) prismatic, containing a crystal, less often two crystals, of calcium oxalate (Fig. 102). Several layers of spool cells occur in the Jack bean. At the hilum (Fig. 114) these tissues abruptly end.

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[1] Schleiden: Beiträge z. Entwicklungsgeschichte d. Blütenteile bei den Leguminosen 1838; Schleiden u. Vogl: Ueber das Albumen, ins besondere der Leguminosen; Chalon: Mém. Pub. Soc. Sci., Arts et Let. du Hainaut 1875, p. 55; Beck: Sitzb. K. K. Akad. zu Wien 1878, **79**; Pammel: Bul. Tor. Bot. Club 1886, p. 17; Mattirolo and Buscalioni: Mem. Accad. Szienze Torino. Ser. II, 1892, **42**; M. Kondo: Z. Unters. Nahr.-Genussm. 1913, **25**, 50; works on food histology.

[2] Anat. Atlas, Leipzig, 1900, p. 208.

Parenchyma.—Usually the tissues are more or less spongy, and, in the inner portion, compressed. In the carob and coffee cassia the inner cells are funnel-shaped.

Beneath the hilum (Fig. 114, p^1) is a spongy mass of cells, often thick-walled and sometimes spool-shaped. Directly under the hilum slit of all garden legumes is a sclerenchyma group (*sc*) which is lacking in the carob, coffee cassia, and tamarind and in bean tree seed is replaced by elongated sclerenchyma elements and vessels.

Inner Epiderm.—This is not evident in most species.

Caruncle.—This consists of narrow, radially elongated cells containing, in the case of the hyacinth bean and adzuki, small starch grains (Fig. 114, *Car*).

Hilum Cushion.—The spongy parenchyma cells contain in the case of the hyacinth bean (Fig. 114, *Hc*) and adzuki small starch grains. Kondo[1] in his analytical key divides the seeds into two groups, one with, the other without hilum cushion, the caruncle being regarded as the border of the cushion.

Endosperm.—Most field and garden legumes have no endosperm or one with only a single layer, but alfalfa (Vol. I, Fig. 270), clovers, fenugreek, serradella, and other species have, in addition to an aleurone layer, several rows of cells with mucilaginous secondary thickening that dissolves readily in water. The endosperm of carob (Fig. 235) and coffee cassia also has secondary thickening but this does not dissolve readily. Schleiden[2] as early as 1838 studied the mucilaginous endosperm of legumes, and Nadelmann[3] in 1890 classified numerous species not only according to the presence of mucilage, but also according to reserve material in the cotyledons whether in cell wall (cellulose, amyloid) or cell cavity (aleurone grains, starch grains, fatty oil).

Perisperm.—Carob and coffee cassia are the only species here described with perisperm well differentiated.

Embryo.—The radicle being small, interest centers in the fleshy cotyledons (*C* in following figures).

Epiderms.—Usually the cells are isodiametric but in the pea (Fig. 96) and lentil they are elongated and often parqueted.

Mesophyl.—Isodiametric cells make up all the tissues in most species but palisade cells form an inner layer in soy bean, the clover group, fenugreek, carob, and coffee cassia. The cell walls are either thin and characterless or else more or less thickened and porous with reserve material in the form of cellulose or hemicellulose. Enormously thickened walls staining blue with iodine in potassium iodide, the reaction for so-called amyloid, characterize the cotyledons of tamarind (Fig. 232), reserve carbohydrate being largely in this form. The mesophyl of some species is rich in starch.

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[1] Loc. cit.

[2] Loc. cit.

[3] Prings. Jahrb. wiss. Bot. **21,** Heft 4.

Starch.—The following data on the presence of starch are by tribes: *Genisteæ*, absent in lupines; *Sophoreæ*, present in bean tree seed; *Hedysareæ*, present in peanut and sanfoin, absent in serradella and Japan clover; *Dalbergieæ*, present in tonka bean; *Loteæ*, present in bird's foot clover; *Vicieæ*, abundant in all species; *Phaseoleæ*, abundant in all species but soy bean which contains none or only a trace; *Trifolieæ*, small amount may or may not be present; *Galegeæ*, absent in all species; *Cæsalpiniaceæ*, absent in all species.

Aside from special cases, such as bean tree starch (Vol. I, Fig. 21) which is of the tapioca type, peanut starch (Vol. I, Fig. 214) which is round, and velvet bean starch (Fig. 119) which resembles somewhat potato starch, leguminous starch grains are usually ellipsoidal, kidney-shaped, or irregularly swollen with a so-called elongated hilum showing with polarized light a line between two V's at the ends, thus X (Vol. I, Fig. 37, IV). An elongated hilum is, however, a crystallographic incongruity. Developmental studies by the writers brought out that what appear to be single grains in the mature seed of certain species, such as common bean (Fig. 102) and smooth pea (Fig. 95), are really semi-aggregates (half-compound grains of Strassburger), with separate rings and excentric hilums formed during the early stages of development, but with outer rings common to the whole, whereas the grains of certain species, such as the wrinkled pea and bean tree, are obviously true aggregates or compound grains, each member with its own hilum and rings. In either case the polarization V's at each end of the grain belong to end members with or without intervening member or members, while the so-called elongated hilum of certain species (e.g., common bean) is a mechanical rift between the two excentric hilums of a twin or through a middle member of three grains attached in a row.

In the starch of the smooth pea the component grains are not always in a row as indicated by swellings and often by polarization crosses but not by lines of separation at maturity, although such lines are often evident in earlier stages of development and are distinctly seen in the grains of the wrinkled pea, even at maturity, the individual grains often actually separating from one another as in the familiar aggregates of oats, rice, etc. In bean tree starch the aggregate nature of the grains is obvious at a glance, and the commercial starch made from this species consists largely of separated individuals.

Aleurone Grains.—These bodies (*al* in the following figures) are of two types: (1) large grains up to about 25 μ containing one or more globoids, occurring when starch is absent, or less often (peanut, tonka bean) in conjunction with starch grains; and (2) minute grains with no visible enclosure occurring as granules in the matrix surrounding starch grains.

Fat.—All leguminous seeds contain a considerable amount of fat or oil and some, such as the peanut and soy bean (see Volume I), a large store.

CHIEF STRUCTURAL CHARACTERS.—Those of the palisade cells, subepidermal cells, and starch grains appear in the table on the following page.

COMPARATIVE CHEMICAL COMPOSITION.—Starchy legumes in general contain 5 to 10 per cent more protein, slightly more fiber and ash, about the same amount of fat, and 5 to 10 per cent less nitrogen-free extract than wheat, whereas non-starchy legumes are true oil seeds rich in both protein and fat (see Soy Bean and Peanut, Volume I). The lupines contain alkaloids.

Proteins.—*Legumin*, a globulin associated with a smaller amount of *vicilin*, also a globulin, and *legumelin*, with characters of both globulins and albumins, occur in the lentil, vetches, broad bean, and smooth pea, all belonging to the *Viciеæ*, and should be looked for in other members of that sub-family.

Phaseolin, characteristic of the sub-family *Phaseoleæ*, is the chief protein of the common bean, the adzuki, and China bean, also presumably of the closely related tepary, scarlet runner, and Dutch case-knife bean. The *concanavalin* of the Jack bean and the *globulins* of the velvet bean, also belonging to the *Phaseoleæ*, closely resemble phaseolin in ultimate composition.

The proteins of the leguminous oil seeds, namely *glycinin* of the soy bean (*Phaseoleæ*), *conglutin* of the lupines (*Genisteæ*), and *arachin* of the peanut (*Hedysareæ*) resemble legumin, at least in ultimate composition.

To what extent the results on amino acids are correlated with those on ultimate composition cannot be determined with the incomplete data on the former now at hand.

The group is large, and the classification, which is based largely on the structure of the flower, may be in some respects faulty; proteins formerly thought to be individuals are being split into two proteins and probably some thought to be distinct are the same. It is believed that as the gaps in the literature are filled the nature of the proteins and histological characters will show still closer relationship.

Alkaloids.—See White and Yellow Lupine.

CHIEF HISTOLOGICAL CHARACTERS OF LEGUMINOUS SEEDS

(Dimensions are maximum in μ)

	Palisade Cells			Subepidermal Cells				Starch Grains	
	Height	Width	End	Height	Width	Shape	Ribs	Type	Diam.
Kamanchile	70	14	flat	15	30	spool	none	minute	6
White lupine	125*	20	flat	70	60	spool	none	none	..
Yellow lupine	135*	20	round	40	40	spool	none	none	..
Blue lupine	135*	20	flat	40	40	spool	none	none	..
Bean tree seed	110	25	flat	40	100	spool	none	compound	22
Peanut	25	50	flat	parenchyma			none	round	15
Tonka bean	60	25	flat	60	50	spool†	none	round	10
Bird-foot clover	35	10	wavy	parenchyma‡			none	none	..
Lentil	45	8	round	25	30	spool	none	legume	40
Broad bean	185	25	flat	75	60	spool	none	legume	65
Spring vetch	70	13	round	27	40	spool	strong	legume	55
Winter vetch	80	11	round	27	40	spool	strong	legume	55
Narrow-leaved vetch	70	13	round	16	40	spool	strong	legume	45
Rough hairy vetch	50	..	round	8	..	spool	strong	legume	27
Smooth pea	90	20	flat	25	50	spool	present	legume	50
Wrinkled pea	90	20	flat	25	50	spool	present	compound	50
Edible-podded pea	80	20	flat	25	50	spool	present	legume	50
Chick pea	160†	20	round	35	35	spool	none	legume	45
Chickling vetch	89	17	round	35	47	spool	present	legume	71
Common bean	60	10	flat	30	30	prism§	none	legume	60
Tepary	45	15	flat	27	15	prism§||	none	legume	35
Scarlet runner	85	15	flat	30	40	prism§||	none	legume	50
Dutch case-knife	50	16	flat	27	25	prism§	none	legume	60
Lima bean	85	20	flat	65	30	spool	none	legume	65
Moth bean	40	15	flat	10	20	spool	none	legume	27
Rice bean	55	15	flat	10	30	spool	none	legume	70
Mung bean	55	15	flat	20	27	spool	none	legume	40
Urd	50	15	flat	15	20	spool	none	legume	27
Adzuki	70	16	flat	15	55	spool	none	legume	80
China bean	70	15	flat	20	20	spool	none	legume	35
Hyacinth bean	155	15	flat	70	60	spool	none	legume	35
Jack bean	220¶	30	flat	60	55	spool**	none	legume	55††
Soy bean	60	20	flat	75	40	spool	none	trace	..
Velvet bean	115	25	flat	45	40	spool	none	ovoid‡‡	40
Red clover	45	15	flat	15	27	spool	strong	minute	..
Crimson clover	45	15	flat	16	40	spool	strong	minute	..
Alsike clover	50	13	round	18	27	spool	strong	minute	..
Alfalfa	35	10	round	6	30	spool	strong	none	..
Fenugreek	85	20	pointed	20	70	spool	strong	trace	..
Tamarind	135§§	10	round	50	25	spool**	none	none|| ||	..
Coffee cassia¶¶	85§§	7	flat	25	25	spool	none	none	..
Carob ¶¶	175	25	flat	35	30	spool	none	none	..

* Geniculate. † Irregular. ‡ Cells within subepiderm spool-shaped. § Oxalate crystal. || Spool-shaped lumen. ¶ 260 μ in Japanese beans. ** Several layers. †† 70 μ in Japanese beans. ‡‡ Excentric hilum, no aggregates. §§ Two bulbs. || || Amyloid in cell wall. ¶¶ Reserve carbohydrate in walls of endosperm.

Fat.—Most garden legumes, like certain cereals, contain too little oil to be profitably expressed, hence results on the composition of the fat are meager. In general it may be stated that the oils range from non-drying to semi-drying, the two leguminous oils of chief commercial importance, namely peanut and soy, representing the extremes. Glycerides of unsaturated acids make up from 75 to 85 per cent of both oils but in peanut oil the ratio of oleic to linolic is about 2 : 1, whereas in soy oil it is about 1 : 2.

Carbohydrates.—In addition to *starch*, considerable amounts of *reducing sugars* and *sucrose* are present in succulent garden legumes. *Paragalactoaraban* was reported by Schulze and coworkers in the eighties as representative of *pentosans* in species of the lupine and pea groups. *Stachyose* and *lupeose* were also identified by them. *Galactose* occurs in certain species.

Mineral Constituents.—In general the ash is richer in potash but poorer in phosphoric acid than wheat.

WHITE LUPINE

Lupinus albus L.

Fr. Lupin blanc. It. Lupini. Ger. Weisse Lupine.

This species of lupine, according to De Candolle, was cultivated by the ancient Greeks and Romans for green manuring and for the seed which was eaten by both man and cattle. The seeds are still used to some extent for human food, after being soaked in water to remove the bitter principle, also, roasted, as a substitute for coffee, but the chief importance of the plant is for soiling, fodder, and as an ornamental.

MACROSCOPIC STRUCTURE.—In this genus the *leaves* are palmate, with several simple *leaflets*, and the *flowers* are in showy racemes. The calyx is conspicuously lipped, the standard reflexed, and the wings united at the top over the inwardly bent keel and style. The *pod* is flat, up to 10 cm. long, hairy, and several-seeded with a conspicuous cross depression between adjoining seeds.

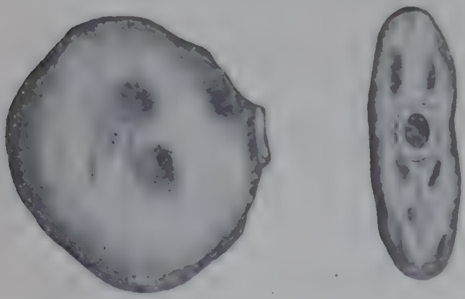

Fig. 84.—White Lupine. Seed. × 2. (A.L.W.)

The flattened, buff *seed* (Fig. 84) has a depression on each side. It is irregularly circular in outline, up to 1.5 cm. in diameter, with the sunken orange hilum (2 mm. long) on a slight projection formed by a concavity between it and the micropyle. On the opposite side the strophiole is 2 to 3 mm. distant from the hilum, the raphe between the two being of an orange color. Only traces of a caruncle and hilum cushion are present.

MICROSCOPIC STRUCTURE.—Sempolowski[1] and Godfrin,[2] in their monographs, and Harz[3] and Vogl,[4] in their treatises, give prominence to this species. The two last-named authors show the seed in cross section.

Spermoderm.—The tissues are: (1) *palisade cells*, up to 125 μ high and 20 μ broad, flat at the outer end, with light line 15 to 20 μ, thick walls and narrow lumen in the outer two-thirds, thin twice-bent walls and broad jagged lumen in the inner third; (2) *subepiderm* of spool-shaped cells up to 70 μ high and 60 μ broad; and (3) thin-walled *parenchyma* of polygonal cells in the outer portion and compressed cells in the inner portion.

Beneath the hilum the cells surrounding the sclerenchyma group are large, thick-walled, and often ribbed, with large intercellular spaces. Many of them resemble the subepidermal cells.

Endosperm.—Not evident.

Embryo.—The walls of the *epiderms* of the cotyledons are non-porous, those of the *mesophyl* porous and moderately thickened. No starch is present—only aleurone grains up to 20 μ each containing a crystalloid or more commonly globoids.

CHIEF STRUCTURAL CHARACTERS.—Seed large, flattened, up to 1.5 cm. in diameter, buff, with sunken sides.

Palisade cells up to 125 μ high and 20 μ broad, flat at outer end, light line 15 to 20 μ, walls thick and lumen narrow in outer two-thirds, walls thinner, twice bent, and lumen jagged in inner one-third; subepidermal cells spool-shaped up to 70 μ high and 60 μ broad; spermoderm parenchyma in outer layers of polygonal, non-porous cells. Epiderm of cotyledon non-porous; mesophyl of moderately thickened, porous cells with aleurone grains up to 20 μ. See also table p. 299.

CHEMICAL COMPOSITION.—See proximate analyses under Yellow Lupine.

Alkaloids.—The alkaloids of the white lupine have been studied by Schmidt and his students Davis, Behrend, Gerhard, Callsen, and Bergh.[5]

Lupanine ($C_{15}H_{24}N_2O$), discovered in the blue lupin by Hagen,[6] was isolated in its dextro form by Bergh from the white lupine and in its dextro and inactive form was obtained by Davis. Dextro-lupanine separates from a saturated solution of the hydrochloride, on adding sodium carbonate, as a colorless oil which later solidifies as silky needles. Inactive (racemic) lupanine consists of lustrous needles, melting at 99° C., readily soluble in ether, chloroform, and other organic solvents. Aqueous solutions of both forms become cloudy on boiling but on cooling again become clear.

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[1] Landw. Jahrb. 1874, **3**, 823.

[2] Soc. Sci. Nancy 1880, p. 109.

[3] Samenkunde, Berlin, 1885, p. 597.

[4] Wicht. Nahr. Genussm., Berlin, 1899, p. 327.

[5] Arch. Pharm. 1897–1904.

[6] Ann. 1885, **230**, 367.

Oxylupanine ($C_{15}H_{24}N_2O_2 + 2H_2O$), as prepared by Bergh, consists of rhombic crystals readily soluble in water, alcohol, ether, and chloroform, but insoluble in petroleum ether. It is dextrorotatory, $[\alpha]_D^{20} + 64.12°$. It is said to occur in white and wild blue lupine.

Fat.—The average percentage of fat in the lupines is intermediate between that of pea, lentil, vetch, broad bean, and navy bean which is low and that of soy bean which is high.

Physical and Chemical Values.—The figures for the fat of white lupine seed, as determined by Grimme,[1] follow: specific gravity at 15° C. 0.923, refractive index at 25° C. 1.4724, saponification number 192.8, iodine number (Wijs) 61.6, ester number 172, total fatty acids 94.3 per cent, titer 24° C., acid number 20.5 (equivalent oleic acid 10.1 per cent), glycerin 9.42 per cent, and unsaponifiable matter 0.98 per cent.

Phosphorus-Organic Compounds.—See Yellow Lupine.

Mineral Constituents.—See Yellow Lupine.

Minor Mineral Constituents. *Iodine.*—Seeds none (Winterstein).[2]

YELLOW LUPINE

Lupinus luteus L.

Fr. Lupin jaune. Ger. Gelbe Lupine.

The yellow lupine is a common soiling and fodder crop, especially in Europe. It is also said to be used for human food, particularly as a substitute for coffee.

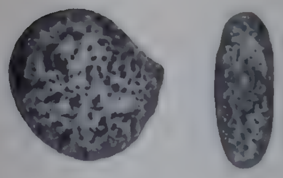

FIG. 85.—Yellow Lupine. Seed. × 2. (A.L.W.)

MACROSCOPIC STRUCTURE.—The *seed* (Fig. 85) is about half the diameter of that of the white lupine and is spotted and blotched with dark brown or black on a buff background. The hilum is about 1 mm. long, in a depression, separated by 1 mm. from the strophiole.

MICROSCOPIC STRUCTURE.—Sempolowski,[3] Harz,[4] Böhmer,[5] and Winton[6] have studied the seed.

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[1] Chem. Rev. Fett-Harz-Ind. 1911, **18**, 53.

[2] Z. physiol. Chem. 1918, **104**, 54.

[3] Landw. Jahrb. 1874, **3**, 823.

[4] Samenkunde, Berlin, 1885, p. 602.

[5] Kraftfuttermittel, Berlin, 1903, p. 345.

[6] Micros. Veg. Foods, New York, 1st Ed. 1906, p. 253.

Spermoderm (Fig. 86).—The layers are: (1) *palisade cells* (*pal*) up to 135 μ high, 20 μ broad, rounded at the top with a light line (*l*) 10 μ broad, thick-walled with a narrow lumen in the outer two-thirds, thinner-walled with a broad and jagged lumen and bent twice in the inner third; (2) *subepiderm* (*sub*) of spool-shaped cells up to 40 μ high and about the same breadth; and (3) *parenchyma* (*p*), polygonal with porous walls (Böhmer) in the outer portion, compressed in the inner portion.

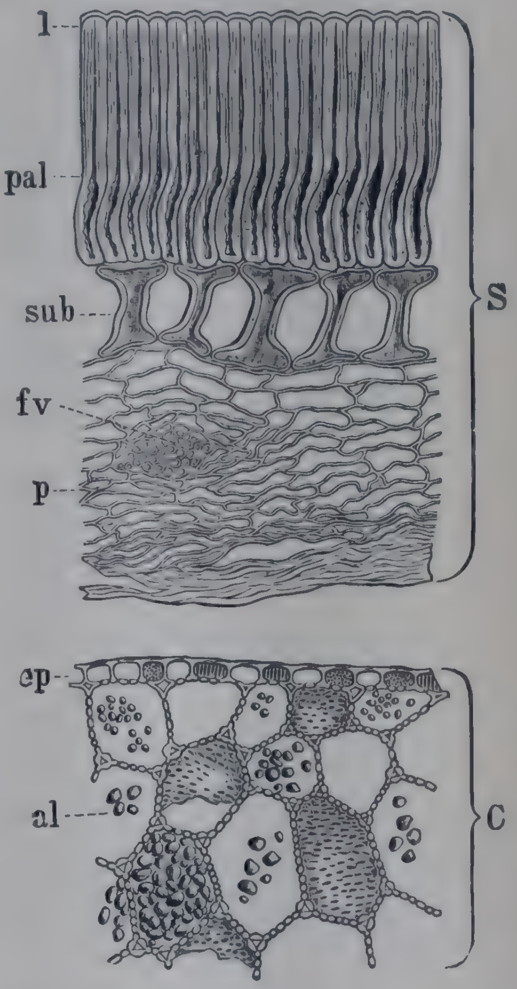

Fig. 86.—Yellow Lupine. Seed in cross section. *S* spermoderm: *pal* palisade cells with *l* light line; *sub* subepiderm; *p* spongy parenchyma with *fv* fibro-vascular bundle. *C* cotyledon with *ep* outer epiderm and mesophyl containing *al* aleurone grains. × 160. (A.L.W.)

The contents of the palisade cells beneath the dark spots are pigmented.

Endosperm.—Not evident.

Embryo (Fig. 86).—In surface view the porous walls of the *epiderms* (*ep*) of the cotyledon (*C*) have a beaded appearance. Cross sections mounted in water show that the porous walls of the *mesophyl cells* are somewhat thickened but not nearly to such an extent as in blue lupine. The contents are *aleurone grains* (*al*) up to 20 μ, some of which contain crystalloids. The cells below the inner epiderm are only slightly elongated.

Chief Structural Characters.—Seed small, spotted, irregularly rounded, flattened, up to 8 mm. in diameter, hilum 1 mm. long in depression.

Palisade cells up to 135 μ high and 20 μ broad, rounded at top with light line 10 μ, inner third bent twice with jagged lumen; subepidermal cells spool-shaped up to 40 μ high and 40 μ broad; parenchyma cells in outer layers polygonal and porous. Epiderm of cotyledon with porous walls, mesophyl cells with porous, moderately thickened walls, containing aleurone grains up to 20 μ. See also table p. 299.

CHEMICAL COMPOSITION.—Although rich in nutrients, seeds of the lupines are distasteful to cattle because of the presence of alkaloidal principles which are not only bitter but may even be unwholesome; on the latter point, however, the evidence is conflicting.

Below are analyses of seeds of the principal economic species compiled from a series of papers by Flechsig, by Täuber, and by Hiller:[1]

PROXIMATE COMPOSITION AND ALKALOIDAL CONTENT OF LUPINE SEEDS

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Alkaloid, solid	Alkaloid, liquid
	%	%	%	%	%	%	%	%
Yellow (*L. luteus*)	15.00	39.21	5.35	26.17	11.06	3.21	0.42	0.39
White (*L. albus*)	15.84	30.46	6.28	34.54	10.56	2.32	0.25	0.02
Blue (*L. angustifolius*)	13.81	30.98	6.41	34.92	11.49	2.39	0.22	0.03
Perennial (*L. polyphyllus*)	11.75	38.16	11.17	35.87	9.68	3.37	0.40	0.08
Hairy (*L. hirsutus*)	11.75	24.54	7.50	39.71	14.04	2.46	0.04	0.00
Cruikshank's (*L. Cruikshanksii*)	11.75	41.59	13.97	23.54	5.93	3.22	0.55	0.45

Analyses made by Guillaume[2] in addition to the usual constituents include determinations of sugar, phosphoric acid, and acidity.

COMPOSITION OF LUPINE SEEDS (GUILLAUME)

	Water	Protein	Fat	N-f. ext. and fiber	Sugars	Ash	P_2O_5	Free acid
	%	%	%	%	%	%	%	%
L. luteus	12.23	37.12	4.17	42.82	9.11	3.66	1.31	0.35
L. albus	10.96	32.81	8.88	44.73	6.33	2.62	0.81	0.24
L. polyphyllus	10.04	34.12	9.70	42.48	6.65	3.66	0.54	0.35
L. Cruikshanksii	10.58	44.62	11.17	29.63	8.81	4.00	0.82	0.47
L. varius	12.18	28.00	5.49	51.38	8.43	2.95	0.87	0.24

Detailed analyses of the kernels and hulls of the yellow lupine have been made by Schulze and coworkers[3] and the composition of the whole seed calculated from these analyses. Determinations of the individual nitrogenous, ether-soluble, and nitrogen-free constituents were also made so far as methods were available. See table next page.

Proteins.—According to Osborne and Campbell,[4] both yellow and blue lupines contain: (1) a globulin *conglutin*, forming 26.2 per cent of the kernel, discovered and named by Ritthausen,[5] (2) a small amount of a *soluble globulin* which unlike conglutin does not precipitate from a

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[1] Landw. Vers.-Stat. 1883, **29** to 1886, **32**.

[2] Bul. sci. pharmacol. 1923, **30**, 529.

[3] Landw. Vers.-Stat. 1891, **39**, 285.

[4] J. Am. Chem. Soc. 1897, **19**, 454.

[5] J. prakt. Chem. 1881, **24**, 221; 1882, **26**, 422.

10 per cent salt solution on adding two volumes of water, (3) *water-soluble protein* forming 0.37 per cent of the kernel and consisting of proteose with either a very soluble globulin or an albumin, (4) a small amount of a *glutelin* or alkali-soluble protein, and (5) a small amount of nitrogenous matter presumably protein insoluble in dilute alkali.

Composition of Yellow Lupine Seeds (Schulze et al.)
(Results calculated to dry basis)

	Kernel	Hull	Whole seed
	%	%	%
Protein *	48.39	3.81	36.79
Nuclein and plastin	0.24	0.88	0.67
Alkaloids	1.46	....	1.08
Fat (ether extract)	8.53	0.79†	6.53‡
Lecithin in fat	2.13	....	1.58
Cholesterol in fat	0.17	....	0.13
Soluble organic acids	2.15	....	1.59
Lupeose	8.38	5.47	7.63
Paragalactoaraban	9.57	17.91	11.73
Fiber	5.52	54.34	18.21
Ash	4.31	1.73	3.64
Undetermined	11.06	15.07	12.13

* N × 5.66. † Lupeol, etc. ‡ Lupeol 0.21 %.

Ultimate Composition.—Ritthausen[1] extracted conglutin with weak alkali, also, as did Osborne and Campbell, with 10 per cent salt solution.

Ultimate Composition of Yellow Lupine Proteins

	Ritthausen	Osborne and Campbell		
	Conglutin	Conglutin	Soluble globulin	Glutelin
	%	%	%	%
Carbon	50.49	50.91	49.58	51.40
Hydrogen	7.03	6.88	6.80	6.79
Nitrogen	18.19	17.93	18.27	16.43
Sulphur	24.29	0.52	1.42	1.03
Oxygen		23.76	20.93	24.35
	100.00	100.00	97.00	100.00

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[1] J. prakt. Chem. 1881, **24**, 221; **26**, 1882, 422.

Amino Acids of Conglutin.—It is not generally known that Ritthausen,[1] working alone and in cooperation with Kreusler, obtained by the slow acid hydrolysis of conglutin, legumin, and several other proteins four amino acids, namely, *tyrosin*, *leucin*, *glutamic acid*, and *aspartic acid*, and determined quantitatively the amounts of glutamic acid and aspartic acid thus formed. Had work along this line, so well begun, been then continued, it is reasonable to believe that the puzzle of protein constitution would have been solved a generation earlier.

In 1901 Schulze and Winterstein[2] determined quantitatively the amounts of the hexone bases, and somewhat later Abderhalden and Herrick[3] and Abderhalden,[4] employing Fischer's method, isolated and determined the individual monoamino acids. The following percentages are those found by Abderhalden and Herrick except where otherwise noted:

AMINO ACIDS OF CONGLUTIN

	%
Glycocoll	0.8
Alanine	2.5
Valine	1.1
Leucine	6.8
Serine	+
Cystine	....
Aspartic acid	3.0
Glutamic acid	19.5*
Tyrosine	2.1
Phenylalanine	3.1
Proline	2.6
Tryptophane	+
Arginine	6.9†
Lysine	2.1†
Histidine	0.63†
Ammonia	....
	51.13

* Abderhalden. † Schulze and Winterstein.

Alkaloids.—The percentages of alkaloids in the different lupines appear above in the first table under Chemical Composition.

The presence of alkaloids in lupines was first demonstrated by

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[1] J. prakt. Chem. 1868, **103**, 233; 1869, **106**, 445; 1869, **107**, 218; 1871, n.f. **3**, 307, 314; 1882, **26**, 504.

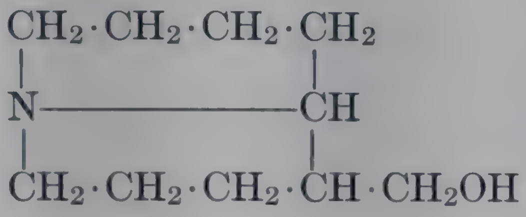
[2] Z. physiol. Chem. 1901, **33**, 547.

[3] Ibid. 1905, **45**, 479.

[4] Ibid. 1906, **47**, 358.

Cassola.[1] Siewert[2] separated them into one crystalline and two liquid substances, assigning formulas to each. Baumert[3] isolated a crystalline alkaloid which he named *lupinine* and regarded as having the formula $C_{21}H_{40}N_2O_2$. He further showed that only one liquid alkaloid *lupinidine* is present, claiming for it the formula $C_8H_{15}N$. Willstätter and Fournau[4] corrected and simplified Baumert's formula for lupinine as shown below, and Willstätter and Marx[5] showed that lupinidine is identical with *sparteine*.

Lupinine ($C_{10}H_{19}ON$) forms colorless tabular crystals, soluble in fat solvents. It is levorotatory and non-reducing. Karrer, Canal, Zohner, and Widmer[6] consider that of two possible formulas the following is the more probable:



Lupinidine or *sparteine* ($C_{15}H_{26}N$) was first found in the common heath by Stenhouse.[7] It is a colorless, thick liquid, boiling at 311° C., with a characteristic odor and bitter taste. It is somewhat soluble in water and readily soluble in chloroform, ether, and alcohol. It is levorotatory; undiluted $[\alpha]_D^{20} - 5.96°$. Karrer, Shibata, Wettstein, and Jacubowicz[8] believe that sparteine has a formula similar to that of lupinine.

Lupanine and *oxylupanine* occur in white and blue lupine but do not appear to be present in the yellow species.

Spathulatine ($C_{33}H_{64}O_5N_4$), a new crystalline alkaloid, has been isolated by Couch[9] from the seeds and pods of *L. spathulatus* Rydb., a plant growing in Utah and Colorado. Whether this occurs in other species is yet to be determined.

Removal of Alkaloids.—Various methods have been proposed for removal of the bitter principles from lupine seeds, such as digestion with hot and then with cold water, with weak alkali, with brine, and with weak mineral acid, but in all these a certain amount of the valuable constituents as well as the alkaloid is removed and the residual matter is rendered more indigestible. Römer[1] approaches the problem by attempting to develop varieties with smaller alkaloid content. Crossing experiments were abandoned as the hybrids did not produce fertile seeds. Selection appears to be a more promising plan.

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[1] Ann. 1835, **13**, 308.

[2] Landw. Vers.-Stat. 1867, **9**, 168.

[3] Ber. 1881, **14**, 1150, 1321, 1880, 2701; 1882, **15**, 631, 1951; Landw. Vers.-Stat. 1881, **27**, 15, 25; 1884, **30**, 295; 1885, **31**, 139.

[4] Ber. 1902, **35**, 1914.

[5] Ibid. 1904, **37**, 2351.

[6] Helv. Chim. Acta 1928, **11**, 1062.

[7] Ann. 1851, **78**, 15.

[8] Helv. Chim. Acta 1930, **13**, 1292.

[9] J. Am. Chem. Soc. 1924, **46**, 2507.

Fat.—See White Lupine.

Carbohydrates.—As is indicated by the analyses of Schulze and coworkers given under the appropriate heads, the same carbohydrates appear to be present in the yellow lupine as in the pea, vetch, and broad bean, but the percentage of *lupeose* and of fiber is greater even if no allowance is made for the sucrose included with the lupeose in the case of the pea group. The percentage of *paragalactoaraban* is also presumably greater since the cell walls of the cotyledons are markedly thicker, although Schulze's quantitative results, not being on the same basis, fail to establish the difference.

Lupeose, first found by Beyer[2] in lupines and later prepared in pure form by Schulze and his students[3] from lupines and various other legumes, is a non-reducing amorphous tetrasaccharide with a strong dextrorotation (+148.0). For a time it was considered to be a disaccharide and was termed β-galactan in Schulze's earlier work. Although it is now known to agree with stachyose in its rotation, in the carbohydrates into which it splits on hydrolysis, and in the amount of mucic acid formed on oxidation, it fails to crystallize as does stachyose, hence Schulze regards the two substances as not identical.

Stachyose or mannatetrasaccharide ($C_{24}H_{42}O_{21} + 4H_2O$) was discovered by Tanret[4] in the roots of *Stachys tuberifera* and other plants of the mint family and more recently[5] in the seeds of several of the common legumes including the lupine and pea groups. It is crystalline, soluble in water, non-reducing, and strongly dextrorotatory (+148). On hydrolysis with acids it yields equal molecules of dextrose and levulose and two molecules of *d*-galactose.

Paragalactoaraban ($C_{16}H_{28}O_{14} + 2H_2O = 2C_5H_{10}O_5 + C_6H_{12}O_6$) occurs according to Schulze[6] in lupines, peas, and other leguminous seeds. On hydrolysis by acids or enzymes, it yields *d*-galactose and *l*-arabinose. Its formula was established by Heiduschka and Tettenborn,[1] who prepared compounds with copper, lead, and zinc salts.

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[1] Landw. Jahrb. 1917, **50**, 433.

[2] Landw. Vers.-Stat. 1867, **9**, 117; 1871, **14**, 164.

[3] Ber. 1886, **19**, 827; 1887, **20**, 280; 1892, **25**, 2213; 1910, **43**, 2230.

[4] Compt. rend. 1903, **136**, 1569.

[5] Ibid. 1912, **155**, 1526.

[6] Ber. 1889, **22**, 1192.

Phosphorus-Organic Compounds. *Lecithin.*—Schulze[2] found in the dry matter of the yellow lupine 1.55 to 1.59 per cent of lecithin. Later he[3] prepared lecithin from the yellow lupine containing 3.46 to 3.76 per cent of phosphorus.

From the ether extract of white lupine Winterstein and Stegmann[4] obtained a phosphatide fraction containing 3.59 to 3.67 per cent of phosphorus, 0.90 to 0.98 per cent of nitrogen, and 15.70 to 16.61 per cent of carbohydrate. Judging from the phosphorus content these preparations were indentical with the lecithin of Schulze.

The presence of carbohydrates in other plant lecithins has been demonstrated by Winterstein and his coworkers.

Enzymes.—Seeds of the common lupines contain diastatic, peptic, glucosidal, and ureal enzymes which have been studied by Muenk.[5]

Mineral Constituents.—Accurate though early analyses of the ash of yellow and blue lupine seeds were made by Heiden.[6]

COMPOSITION OF LUPINE SEED ASH (HEIDEN)

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
Yellow.	29.49	0.29	8.19	12.68	0.61	44.29	4.34	. . . . . .	0.12
Blue.	31.90	0.81	9.87	10.91	0.73	39.04	5.58	0.34	0.59

Minor Mineral Constituents. *Manganese.*—Air-dry lupines, containing 3.66 per cent of ash, 6.22 mg. per kilo, equivalent to 1700 mg. in 100 grams of ash (Wester).[7]

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[1] Biochem. Z. 1927, **189**, 203.

[2] Landw. Jahrb. Schweiz, 1892, **6**, 72.

[3] Z. physiol. Chem. 1907, **52**, 54.

[4] Ibid. 1909, **58**, 500.

[5] Landw. Vers.-Stat. 1914, **85**, 393.

[6] Ibid. 1866, **8**, 455.

[7] Biochem. Z. 1921, **118**, 158.

BLUE LUPINE

Lupinus angustifolius L.

Fr. Lupin bleu. Ger. Blaue Lupine.

Like the white and yellow species, the blue lupine is grown chiefly for soiling and fodder. Hanausek[1] states that the seed is used as a coffee substitute in Hungary.

MACROSCOPIC STRUCTURE.—The *plant* has narrow leaves and the *flower* is blue. The *seeds* (Fig. 87) are thicker and more nearly spherical than those of yellow lupine. They vary up to 8 mm. long and are of a dull brown-gray color blotched with brown and buff. The depressed hilum (1 mm.) and the strophiole are 2 mm. apart.

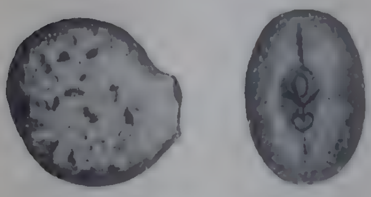

FIG. 87.—Blue Lupine. Seed. × 2. (A.L.W.)

Varieties *leucospermus* and *leucanthus* have dirty white seeds. In the former the flowers are blue, in the latter white.

MICROSCOPIC STRUCTURE.—Harz[2] briefly notes certain tissues: Hanausek[1] gives several illustrations and a full description.

Spermoderm.—In our material the structure is practically the same as that of yellow lupine, except that the outer ends of the palisade cells are flat and the light line is narrower (maximum 6 μ).

Endosperm.—Harz finds traces of an endosperm.

Embryo.—As seen in surface view, pores are present in the radial walls of the *epiderms* of the cotyledons, giving them a beaded appearance, also around the edges of the inner tangential walls where they reach considerable size. Although the aleurone grains are practically the same as in white and yellow lupine, the cell walls of the *mesophyl*, in sections mounted in water, are very much thicker, particularly at the angles, on account of swelling.

CHIEF STRUCTURAL CHARACTERS.—Seed up to 8 mm. long, more nearly globular than that of yellow lupine, dull brown-gray blotched with brown and buff.

Spermoderm as in yellow lupine, except that the outer ends of the palisade cells are flat and the light line is narrower. Epiderms of cotyledon with radial walls and edges of inner tangential walls porous; cell walls of mesophyl porous and much swollen; aleurone grains up to 20 μ. See also table p. 299.

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[1] Dammer: Lex. Verfäls., Leipzig, 1885, **1**, 395.

[2] Samenkunde, Berlin, 1885, p. 600.

CHEMICAL COMPOSITION.—See proximate analyses under Yellow Lupine.

Proteins.—Preparations of the globulin, *conglutin*, made from the sodium chloride extract by Ritthausen[1] and by Osborne and Campbell,[2] had the following ultimate composition:

Ultimate Composition of Conglutin

	Ritthausen	Osborne and Campbell
	%	%
Carbon	50.39	51.13
Hydrogen	6.94	6.86
Nitrogen	18.22	18.11
Sulphur	0.49	0.32
Oxygen	23.96	23.58
	100.00	100.00

Alkaloids.—*Lupanine* (see White Lupine) occurs in the wild blue lupine (*L. perennis* L.).

Mineral Constituents.—See Yellow Lupine.

Minor Mineral Constituents. *Iodine.*—Seeds none (Winterstein).[3]

LENTIL

Lens esculenta Moench = *Ervum lens* L.

Fr. Lentille. Sp. Lenteja. It. Lente. Ger. Linse.

Since prehistoric times the lentil has been cultivated in the Mediterranean region where it doubtless originated. Esau sold his birthright for a mess of pottage made from lentils. The Greeks and Romans cultivated lentils, and the Latin name lens was applied to a double convex magnifying glass because of its resemblance to the lentil.

Dried lentils are a common food product in Europe but in America are eaten mostly by the foreign population.

MACROSCOPIC STRUCTURE.—The *plant* is low, the *leaflets* of the pinnate leaf small, the terminal one developed as a tendril. Among the distinguishing characters of the small *flower* are its white or lavender color, the elongated nearly uniform calyx lobes, the partially united wings and short keel, and the style, flattened on the outer face and hairy along the inner.

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[1] J. prakt. Chem. 1868, **103**, 233; 1881, **24**, 221; 1882, **26**, 422.
[2] J. Am. Chem. Soc. 1897, **19**, 454.
[3] Z. physiol. Chem. 1918, **104**, 54.

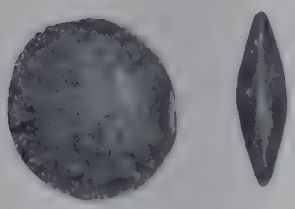
FIG. 88. — Lentil. Seed. × 2. (A.L.W.)

The short but relatively broad *pod* normally contains two lenticular sharp-edged *seeds* (Fig. 88) up to 8 mm. in diameter, in color green-yellow, brown, dark red, or black. Under a lens the narrow hilum 1 to 2 mm. long, without accompanying caruncle or hilum cushion, the strophiole, and the micropyle are evident.

MICROSCOPIC STRUCTURE (Fig. 89).—Details of structure appear in the works on food histology.

Spermoderm (*S*).—The tissues are (1) *palisade cells* (*pal*) rounded at top, up to 45 μ high and 8 μ wide, with thin cuticle and light line (*l*) up to 6 μ, (2) *subepiderm* (*sub*) of spool-shaped cells, up to 25 μ high and 30 μ broad, and (3) *parenchyma* (*p*) mostly spongy with large cells, except in the inner portion where they are small and compressed.

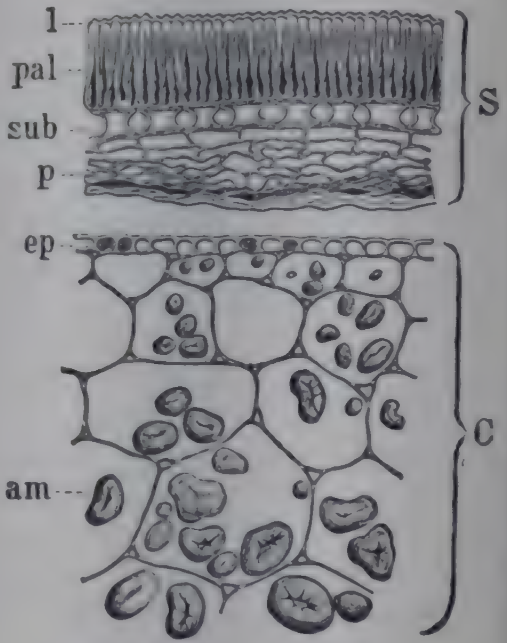

FIG. 89.—Lentil. Seed in cross section. *S* spermoderm: *pal* palisade cells with *l* light line; *sub* subepiderm; *p* spongy parenchyma. *C* cotyledon with *ep* outer epiderm and mesophyl containing *am* starch grains. × 160. (A.L.W.)

The cells about the sclerenchyma group beneath the hilum are small, thick-walled, with colored contents and small intercellular spaces.

Endosperm.—Not evident.

Embryo.—The *epiderms* (*ep*) of the cotyledons (*C*) consist of tangentially elongated cells, more or less parqueted, and the *mesophyl* of thin-walled cells without palisade cells. *Starch grains* (*am*) up to 40 μ, embedded in a protein-rich matrix, are present throughout the mesophyl. Ellipsoidal and reniform grains often with rifts predominate. Irregular aggregate or semiaggregate grains are not infrequent.

CHIEF STRUCTURAL CHARACTERS.—Seeds lenticular with minute hilum, strophiole, and micropyle.

Palisade cells narrow, with rounded outer ends, up to 45 μ high; subepidermal cells spool-shaped, up to 25 μ high. Endosperm not evident. Cotyledon with tangentially elongated epidermal cells and isodiametric mesophyl cells; starch grains 40 μ, smaller than in pea, mostly ellipsoidal with rifts. See also table p. 299.

CHEMICAL COMPOSITION.—A summary of analyses by Balland[1] and of 3 analyses compiled by Atwater and Bryant[2] follows:

Composition of Lentils

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Balland:						
Min.	11.70	20.32	0.58	56.07	2.96	1.99
Max.	13.50	24.24	1.45	62.45	3.56	2.66
A. and B.:						
Min.	6.4	24.5	0.7	58.6		3.2
Max.	10.7	26.6	1.5	59.8		8.6
Aver.	**8.4**	**25.7**	**1.0**	**59.2**		**5.7**

Proteins.—The ultimate analyses of the proteins, prepared by Osborne and Campbell[3] from the lentil, indicate that they are the same as those in the pea (which see), vetch, and broad bean. Results on the kind and amounts of the amino acids sufficient to prove the absolute identity of the proteins of the different species are, however, lacking.

Ultimate Composition of Lentil Proteins (Osborne and Campbell)

	Legumin	Vicilin	Legumelin	Proteose
	%	%	%	%
Carbon	51.73	52.13	53.22	50.17
Hydrogen	6.89	7.02	6.82	6.77
Nitrogen	18.06	17.38	16.27	16.81
Sulphur	0.40	0.17	0.94	1.27
Oxygen	22.92	23.30	22.75	24.98
	100.00	100.00	100.00	100.00

Amino Acids of Lentil Proteins.—The following figures for *cystine* and *tryptophane* respectively are by Jones, Gersdorff, and Moeller:[4] legumin 0.68 and 0.93; vicilin 0.40 and 0.68 per cent.

[1] Compt. rend. 1897, **125**, 119.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[3] J. Am. Chem. Soc. 1898, **20**, 362.

[4] J. Biol. Chem. 1924, **62**, 183.

Fat.—No data available.

Carbohydrates.—*Stachyose* has been found by Tanret[1] to be present, as are probably the other carbohydrates named under Smooth Pea. *Galactose* was identified by Tractta-Mosca (see Common Bean).

Mineral Constituents.—In Wolff's compilation[2] an analysis by Levi is given as follows:

COMPOSITION OF LENTIL ASH (LEVI)
(Per cent of ash 2.06)

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	Cl
% 34.76	% 13.50	% 6.34	% 2.47	% 2.00	% 36.30	% 4.63

The percentage of soda in this analysis is unreasonably high.

Minor Mineral Constituents. *Manganese.*—Seeds 32.5 mg. per kilo, air-dry basis (Quartaroli).[3]

Aluminum.—Seeds, green 1 mg. per kilo, dry basis (Bertrand and Lévy).[4]

Copper.—Seeds 5.26 mg. per kilo, air-dry basis (Quartaroli).[3] Seeds 6.6 mg. per kilo, air-dry basis (Guérithault).[5]

Zinc.—Seeds 24.5 mg. per kilo, air-dry basis (Bertrand and Benzon).[6]

Arsenic.—Seeds 0.1 mg. per kilo (Jadin and Astruc).[7]

BROAD BEAN

Vicia Faba L. = *Faba vulgaris* Moench. = *F. sativa* Bernh.

Fr. Féverole. It. Fava. Ger. Pferdebohne.

Horse bean and Windsor bean are other names for this species. It has been cultivated since prehistoric times in countries bordering on the Mediterranean. De Candolle believes that it originally grew in two regions, one south of the Caspian, the other in northern Africa. Formerly the most important and still in some countries the commonest bean, the seed now is less highly esteemed for human food than species of *Phaseolus*. It is still popular with the poorer classes in parts of

[1] Compt. rend. 1903, **136**, 1569.
[2] Aschenanalyzen.
[3] Ann. chim. appl. 1928, **18**, 47.
[4] Bul. soc. hyg. aliment. 1931, **19**, 359.
[5] Compt. rend. 1920, **171**, 196.
[6] Bul. soc. hyg. aliment. 1928, **16**, 357.
[7] Compt. rend. 1912, **155**, 291.

Europe, such as Italy and Spain, and with emigrants from those regions in the United States. It also is eaten at the snap stage. Its chief importance in most countries at present is as a cattle food.

MACROSCOPIC STRUCTURE.—From the common vetches, the *plant* is distinguished by the absence of well developed tendrils. The *flower* is whitish with a dark purple spot on each wing. The *pod* is more or less downy, thick-walled, up to more than 7 cm. in length.

The *seeds* (Fig. 90) are in cavities separated by spongy partitions. They are ellipsoidal, often rounded-rectangular, green, brown, purple, or black, and vary greatly in size according to the variety. Harz[1] divides the species into three botanical varieties: (1) *minor* with seeds up to 13 mm., (2) *equina*, seeds up to 2 cm., and (3) *major*, seeds up to 3.5 cm., with sub-varieties under each. Tibbles[2] groups as broad or Windsor beans varieties with seeds up to 2.5 cm., as horse beans or ticks those under 1.5 cm. in length.

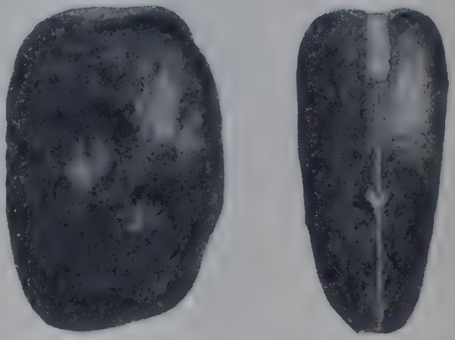

FIG. 90.—Broad Bean. Seed. × 2. (A.L.W.)

A character common to all is the location of the *hilum* (which often exceeds 5 mm. in length) in a depression at the end of the seed. Except for the barest traces, caruncle and hilum cushion are lacking. The strophiole is 5 mm. or more from the end of the hilum, and from the strophiole the raphe extends to the chalaza at a point about opposite the hilum. The seeds have commonly one or more depressions on each side.

MICROSCOPIC STRUCTURE (Fig. 91).—Godfrin[3] and Sempolowski[4] in their monographs, as well as various authors in their hand books, have described this common legume.

Spermoderm (*S*).—Cross sections show: (1) *palisade cells* (*pal*) up to 185 μ high and 25 μ broad, flattened at the outer end, with a light line (*l*) up to 25 μ broad, and with lumen broadening toward the inner end; (2) *subepiderm* (*sub*) of spool-shaped cells up to 75 μ high and 60 μ broad; and (3) *parenchyma cells* (*p*), largest in the middle, smallest in the inner portion where the tissue is very spongy and compressed.

The radial walls of the *palisade cells*, in the inner half, are often thin and sinuous, and the lumen contains the dark-colored substance to which the seed owes its color.

---

[1] Samenkunde, Berlin, 1885, p. 661.

[2] Foods, etc., London, 1912, p. 529.

[3] Soc. Sci. Nancy 1880, p. 109.

[4] Landw. Jahrb. 1874, **3**, 823.

Beneath the hilum the loosely arranged cells about the large sclerenchyma group are thick-walled, spool- or bone-shaped, resembling the subepidermal cells, although much shorter and with dark contents such as are contained in the outer parenchyma into which the tissue passes. More remote from the hilum, dark contents are often present in the middle parenchyma.

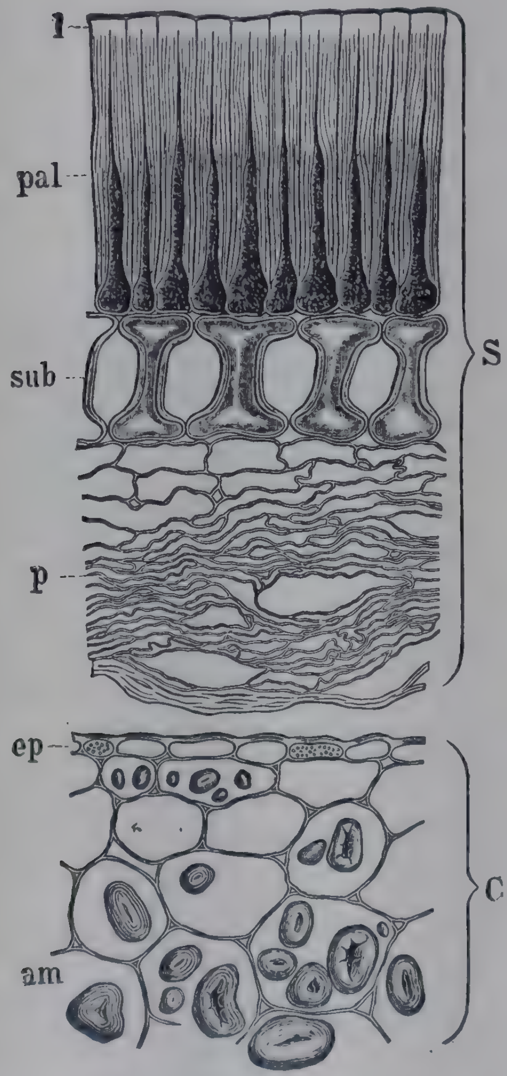

FIG. 91.—Broad Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *l* light line; *sub* subepiderm; *p* spongy parenchyma. *C* cotyledon with *ep* outer epiderm and mesophyl containing *am* starch grains. ×160. (A.L.W.)

Endosperm.—None evident at maturity.

Embryo.—The *epidermal cells* (*ep*) of the cotyledons (*C*) show a tendency to quadrilateral form. Although often two or three times as long as broad, they are not of the narrow, strongly elongated type of the pea and lentil. The *mesophyl* is of thin-walled more or less isodiametric cells throughout. *Starch grains* (*am*), reaching 65 μ in length, are present in all the cells, except those of the epiderm. Among the forms are ellipsoidal, reniform, rounded-triangular, and nearly spherical. Rifts may or may not be present.

CHIEF STRUCTURAL CHARACTERS.—Seeds up to 3.5 cm., ellipsoidal, often tending toward rectangular, with hilum at one end and 5 mm. or more from strophiole.

Palisade cells up to 185 μ high and 25 μ broad; subepidermal cells spool-shaped, up to 75 μ high and 60 μ broad. Endosperm lacking. Epidermal cells of cotyledon only moderately elongated; mesophyl thin-walled without palisade cells; starch grains up to 65 μ. See also table p. 299.

CHEMICAL COMPOSITION.—The composition of the beans and their products is fully treated by Koehler.[1] The following figures are credited to Dietrich and König.[2]

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[1] Landw. Vers.-Stat. 1901, **55**, 401.

[2] Zusam. Verd. Futterm. 1891.

Composition of Broad Bean (Dietrich and König)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	7.87	17.68	0.81	41.25	2.87	1.73
Max.	17.85	31.54	3.29	59.01	18.17	4.70
Aver.	**13.49**	**25.31**	**1.68**	**48.33**	**8.06**	**3.13**

Schulze and Märcker[1] found that the hulls, forming 15.68 per cent of the whole seed, contain on the dry basis: protein 7.00, fat 0.98, nitrogen-free extract 37.86, fiber 52.42, and ash 1.74 per cent.

The following analysis, by Schulze, Steiger, and Maxwell[2] is comparable with those of smooth pea and Spring vetch reported by the same authors: true protein 22.81, nuclein (and plastin?) 1.91, glycerides and free fatty acids 1.26, cholesterol 0.04, lecithin 0.81, soluble organic acids 0.88, sucrose and lupeose 4.23, starch 42.66, paragalactoaraban, etc. 15.33, fiber 7.15, and ash 2.92; total 100 per cent.

Composition of Large and Small Beans.—Gwallig[3] found that large beans regardless of variety or fertilizer are about 10 per cent richer in protein and fat but about 20 per cent poorer in fiber than small beans of the same crop. Nitrogen-free extract and ash showed smaller differences.

Proteins.—The proteins, judged by the ultimate analyses of Osborne and Campbell[4] as given below, are indistinguishable from those of the smooth pea (which see).

Ultimate Composition of Broad-Bean Proteins (Osborne and Campbell)

	Legumin	Vicilin	Legumelin	Proteose	
				I	II
	%	%	%	%	%
Carbon	51.72	52.38	53.03	50.24	49.96
Hydrogen	7.01	7.04	6.97	6.66	6.76
Nitrogen	18.06	17.52	16.22	17.11	16.95
Sulphur	0.39	0.15	1.30	1.87	2.75
Oxygen	22.82	22.91	22.48	24.12	23.58
	100.00	100.00	100.00	100.00	100.00

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[1] Wolff: Ernähr. Landw. Nutztiere.

[2] Landw. Vers.-Stat. 1891, **39**, 297.

[3] Landw. Jahrb. 1894, **23**, 835.

[4] J. Am. Chem. Soc. 1898, **20**, 393, 410.

Legumin and vicilin formed together about 17 per cent, legumeli almost 1.25 per cent, and proteose about 0.5 per cent of th bean.

Fat.—The ether and benzine extracts yielded, in the analyses b Stellwaag,[1] respectively:

	Melt. pt.	Sapon. No.	Neutral fat	Fatty acids, total	Fatty acids, free	Lecithin	Unsapon matter
	° C.		%	%	%	%	%
Ether extract. .	below 10	188.0	57.70	79.93	9.82	21.29	5.92
Benzine extract	" 10	180.4	80.17	89.52	9.70	4.11	6.90

Phosphorus-Organic Compounds. *Lecithin.*—Schulze and Frankfurt[2] found 0.81 per cent in the dry matter of the seed.

Phosphatides and Lecithides.—The work of Magistris and Schäfer[3] is of interest chiefly because they conclude that no true lecithin is present in the cells, the lecithin isolated being a denatured product of the water-soluble phosphatides. They designate as phosphatides substances separated by dialysis in the cold against water, using a diluted mixture of ethyl and caprylic alcohols, and as lecithides substances, resembling lecithin, extracted by organic solvents. Phosphatides obtained by precipitation with a mixture of ethyl alcohol, methyl alcohol, and acetone and by precipitation in the filtrate with calcium chloride contained respectively P 2.04 and 1.11, N 1.14 and 2.36, and reducing matter calculated as dextrose 15.08 and 5.99. Three lecithides extracted by various solvents contained P 1.59 to 3.45, N 0.89 to 1.70, and reducing matter calculated as dextrose 1.98 to 10.94 per cent.

Phytin.—From the results of solubility experiments, employing acid and alkaline solutions, Mnich[4] concluded that at certain *p*H readings phytin combines with proteins forming insoluble compounds.

Enzymes.—In the variety *minor*, Blagovyeshchenskii[5] notes that the amount of *amylase* at different stages of development is in general correlated with the amount of starch formed, from which he concludes that amylase is instrumental in the synthesis of starch.

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[1] Landw. Vers.-Stat. 1890, **37**, 135.
[2] Ibid. 1893, **43**, 30.
[3] Biochem. Z. 1929, **214**, 401.
[4] Bul. intern. acad. polonaise, Classe sci. math. nat. B, **I 1931**, p. 123.
[5] J. Russ. Phys. Chem. Soc. 1915, **47**, 1529.

Mineral Constituents.—An ash analysis by Wolff[1] showed as follows:

Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
3.63	41.48	1.06	4.99	7.15	0.46	38.86	3.39	1.78	0.65

Minor Mineral Constituents. *Manganese.*—Seeds 1.5 mg. per kilo, dry basis (Wester).[2] Seeds 9.40 mg. per kilo, air-dry basis (Quartaroli).[3]

Copper.—Seeds 8.0 mg. per kilo, dry basis (Hirano and Mikumo).[4] Seeds 30.8 mg. per kilo, air-dry basis (Quartaroli).[3]

SPRING VETCH

Vicia sativa L.

Fr. Vesce. Sp. Alverja. It. Veccia. Ger. Futterwicke.

Common or Spring vetch—the latter is a misnomer as in sections this plant is grown as a Winter crop—also known as tare, but not the tare of the Bible, grows wild in most parts of Europe, northern Africa, and western Asia. It was cultivated by the Romans. Today it is grown extensively in Europe chiefly for green fodder or hay (see Fodder Plants, Vol. I) although the ripe seeds are used to some extent for feeding and even for human food. The seeds occur in European screenings.

MACROSCOPIC STRUCTURE.—Usually the several-seeded *pod* is hairy, compressed, less than 8 cm. long. Even in the same variety the *seeds* are partly self-colored, varying from light to dark brown, and partly spotted or marked with black and two shades of brown. The common form is lenticular approaching spherical, up to 5 mm. in diameter. Some kernels are somewhat elongated up to 6 mm. The narrow white hilum is 1.5 to 2 mm. long, the strophiole being less than 1 mm. from one end and the micropyle immediately adjoining the other end. Neither caruncle nor hilum cushion is present.

MICROSCOPIC STRUCTURE (Fig. 92). **Spermoderm** (*S*).—As the inner epiderm is structureless at maturity, the tissues may be classified under three heads: (1) *palisade cells* (*pal*), up to 70 μ high and 13 μ broad, rounded at the outer end, with cuticle (*cut*) and light line (*l*); (2) *subepiderm* (*sub*) of spool- or capstan-shaped cells up to 27 μ high and 40 μ broad, with strongly ribbed and thickened radial walls and pitted inner tangential walls, containing chlorophyl grains; and (3) *parenchyma* varying from normal cells (p^1), with small intercellular spaces, containing chlorophyl grains, to spongy parenchyma (p^2), and finally, in the inner portion, to compressed spongy parenchyma (p^3).

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[1] Aschenanalysen.

[2] Biochem. Z. 1921, **118**, 158.

[3] Ann. chim. appl. 1928, **18**, 47.

[4] J. Pharm. Soc. Japan 1925, **525**, 992.

The color is due to contents of the palisade cells, present chiefly in the inner broadened cavity, also in a zone directly beneath the light line. Brown coloring matter is also present in the spool- or boned-shaped cells present beneath the hilum slit about the sclerenchyma group. These cells, although forming a continuation of the outer parenchyma, are more like the subepidermal cells in form and like them have thick, ribbed walls.

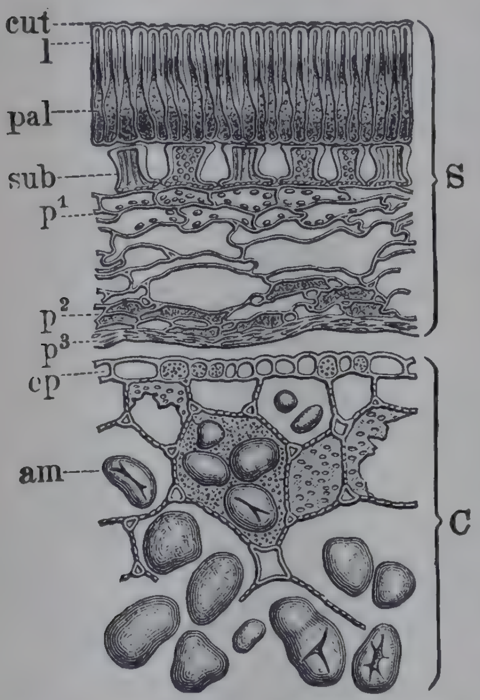

FIG. 92.—Spring Vetch. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line; *sub* subepiderm; p^1 chlorophyl parenchyma; p^2 spongy parenchyma; p^3 compressed parenchyma. *C* cotyledon: *ep* outer epiderm; *am* starch grains. × 160. (K.B.W.)

Endosperm.—Not evident.

Embryo.—As in the pea, the *epiderm* (*ep*) of the cotyledons (*C*) consists of narrow, tangentially elongated cells, but their arrangement in parquetry-like groups is not pronounced. The isodiametric cells of the *mesophyl* are porous (beaded), although less distinctly so than in the common pea. *Starch grains* (*am*) up to 55 μ, of various irregular shapes, with or without rifts, are the conspicuous contents. The compound nature of the grains is often well marked.

CHIEF STRUCTURAL CHARACTERS.—Seeds lenticular to nearly globular, up to 6 mm.; brown, black, or mottled; hilum up to 2mm.

Palisade cells up to 70 μ high and 13 μ broad, with rounded outer ends; subepiderm up to 27 μ high and 40 μ broad, spool-shaped. Mesophyl of cotyledons beaded; starch grains irregular, compound, or half-compound, up to 55 μ, with or without rifts. See also table p. 299.

CHEMICAL COMPOSITION.—In Dietrich and König's compilation[1] the summary given appears on the next page.

Koehler, in his monograph on peas, beans, vetches, and their mill products,[2] gives additional results on the composition of this and other species of vetch including French vetch (*V. narbonensis* L.), which has not found favor in the United States.

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[1] Zusam. Verd. Futterm. 1891.

[2] Landw. Vers.-Stat. 1901, **55**, 401.

Composition of Spring Vetch Seed (Dietrich and König)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	8.99	21.35	1.26	50.10	5.60	2.35
Max.	16.09	28.13	2.70	57.06	7.17	4.60
Aver.	**13.28**	**25.90**	**1.77**	**49.80**	**6.02**	**3.23**

An analysis including the constituents less often determined, made by Schulze, Steiger, and Maxwell,[1] follows: true protein 25.46, nuclein (and plastin?) 2.33, glycerides and free fatty acids 0.91, cholesterol 0.06, lecithin 1.22, soluble organic acids 0.50, sucrose and lupeose 4.85, starch 36.30, paragalactoaraban, etc. 20.58, fiber 4.89, and ash 2.90; total 100 per cent. (See Smooth Pea.)

Proteins.—Osborne and Campbell[2] found in the seed the following approximate amounts of proteins: *legumin* 10 per cent, *vicilin* trace, *legumelin* 1.5 per cent, and *proteose* 0.5 per cent. These proteins had practically the same ultimate composition and properties as those in the pea, lentil, and broad bean.

Ultimate Composition of Proteins of Spring Vetch (Osborne and Campbell)

	Legumin	Legumelin	Proteose
	%	%	%
Carbon	51.69	53.31	50.85
Hydrogen	6.99	6.97	6.75
Nitrogen	18.02	16.24	16.65
Sulphur	0.43	1.11	25.75
Oxygen	22.87	22.37	
	100.00	100.00	100.00

Fat.—The figures of Stellwaag[3] on the ether and benzine extracts are:

	Melt. pt.	Sapon. No.	Neutral fat	Fatty acids, total	Fatty acids, free	Lecithin	Undetermined matter
	° C.		%	%	%	%	%
Ether extract	13	183.6	52.16	80.87	14.81	22.94	7.14
Benzine extract	12	183.6	61.26	80.80	16.73	7.65	9.23

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[1] Landw. Vers.-Stat. 1891, **39**, 297.

[2] J. Am. Chem. Soc. 1896, **18**, 609; 1898, **20**, 406, 410.

[3] Landw. Vers.-Stat. 1890, **37**, 135.

Phosphorus-Organic Compounds. *Lecithin.*—Schulze and Frankfurt[1] found 1.22 and 0.74 per cent in the dry matter of two samples of th seed.

Mineral Constituents.—An analysis given by Wolff[2] of the ash o Spring vetch shows the following percentages of the common constituents:

Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
% 3.10	% 30.14	% 7.86	% 8.03	% 8.95	% 1.27	% 37.35	% 3.69	% 2.71	% 1.31

Minor Mineral Constituents. *Manganese.*—Seeds 1.5 mg. per kilo, dry basi (Wester).[3] Parts of 2 samples of vetch (species not stated) contained: seeds 10 an —, pod 6 and —, blooms 17 and —, leaves 33 and 27, stems 11 and 8 mg. per kil dry matter; hay, 15 samples, contained 17 to 53, aver. **42** mg. per kilo, air-dry basi (Jones and Bullis).[4]

Zinc.—Seeds 23 mg. per kilo, air-dry basis (Bertrand and Benzon).[5]

Iodine.—Seeds none (Winterstein).[6]

WINTER VETCH

Vicia villosa Roth.

Ger. Winterwicke.

The name Winter vetch is used because the plant withstands th northern climate better than Spring vetch. There are, however, Winte varieties of *V. sativa.* Hairy vetch, another name, is also unfortunat since the pod is nearly smooth while that of *V. hirsuta* is rough hairy The leaves and stem although hairy are not much more so than *V. sativ* (see Fodder Plants, Volume I).

MACROSCOPIC STRUCTURE.—Except in size (up to 4.5 mm. the *seeds* are like those of Spring vetch, varying from dark to light, eithe self-color or mottled.

MICROSCOPIC STRUCTURE.—As in Spring vetch, except tha the palisade cells reach 80 μ in height and 11 in breadth.

[1] Landw. Vers.-Stat. 1893, **43**, 307.

[2] Aschenanalysen.

[3] Biochem. Z. 1921, **118**, 158.

[4] J. Ind. Eng. Chem. 1921, **13**, 524.

[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

[6] Z. physiol. Chem. 1918, **104**, 54.

Chief Structural Characters.—As in Spring vetch, except for the smaller size of the seeds and the somewhat higher palisade cells. See also table p. 299.

NARROW-LEAVED VETCH

Vicia angustifolia L.

Ger. Schmalwicke.

Grain fields of Minnesota and adjacent regions are infested with vetch, known in that region as " wild pea." The seeds are particularly objectionable in wheat as they cannot be entirely removed by screens and injure the flavor of flour. Oswald[1] found that vetch was present in 6 per cent of 218 samples of seed wheat, 7.25 per cent of 193 samples of oats, 15.5 per cent of 97 samples of barley, and 16.7 per cent of 12 samples of rye. In private correspondence he states that *V. angustifolia* is the common species in Minnesota, having been first introduced from southeastern Europe into the eastern section of the United States. He adds that it is most prevalent during a wet season.

The authors are further indebted to Professor Oswald for authentic material.

MACROSCOPIC STRUCTURE.—Except for size the appearance of the *seed* (Fig. 93) is like that of the foregoing species. Although variable, some seeds being twice the diameter of others, the maximum diameter seldom exceeds 3.5 mm.

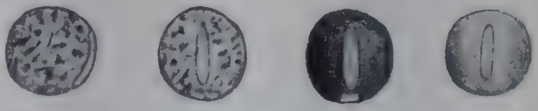

Fig. 93.—Narrow-Leaved Vetch. Seed. × 2. (A.L.W.)

MICROSCOPIC STRUCTURE.—As in Spring vetch, except that the *subepidermal cells* are lower (up to 16 μ) and the *starch grains* seldom exceed 45 μ. See also table p. 299.

Chief Structural Characters.—Seeds and starch grains smaller and subepidermal cells lower than in either Spring or Winter vetch; in other respects the same.

CHEMICAL COMPOSITION.—Gortner[2] reports the following analysis of the air-dry seed:

Composition of Narrow-Leaved Vetch (Gortner)

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
9.55	24.06	2.46	49.58	11.25	3.10

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[1] Minnesota Agr. Exp. Sta. 1912, Bul. **127**, 144.

[2] Breeders' Gaz. 1920, **77**, 1230.

The same author found that the sample yielded 0.0033 per cent of *hydrocyanic acid* (3.3 mg. per 100 gram), but in feeding experiments with pigs and lambs no injurious effects were noted.

Glucoside.—In a study of *vicianin* and its diastase Bertrand and Rivkind[1] tested the seeds of 60 species of legumes of which only those of *Vicia angustifolia* Roth. and *V. macrocarpa* Bertol. contained both the glucoside and its diastase, although most of the seeds contained the diastase.

ROUGH HAIRY VETCH

Vicia hirsuta Koch.

Ger. Rauhhaarige Wicke.

Vogl[2] gives the seeds of this species special prominence as it occurs with *V. Cracca* L. (perennial vetch) and *V. sativa* L. in European grain. The plant grows also in the United States, having been introduced from Europe. The designation rough hairy refers especially to the pods. The following statements are based on Vogl's description.

MACROSCOPIC STRUCTURE.—Length 2.5 mm.; color various combinations of green, brown, red, and black.

MICROSCOPIC STRUCTURE.—*Palisade cells*, up to 50 μ; *sub epiderm*, up to 8 μ; starch grains, up to 27 μ, ellipsoidal, kidney-shaped, etc., showing often in Vogl's illustration the well-marked individuals forming the aggregates.

CHIEF STRUCTURAL CHARACTERS.—Seeds and starch grains smaller than in the foregoing species of *Vicia*. See also table p. 299.

SMOOTH PEA

Pisum arvense L. = *P. sativum* var. *arvense* Poir.

Fr. Pois. Sp. Guisante. It. Pisello. Ger. Erbse.

De Candolle regards the field pea, characterized by its smooth seed, as a native of Italy where it still grows wild. By a reversal of logic, this wild form now is assigned by some a varietal name while the wrinkled garden pea, which is more probably the product of artificial breeding, is regarded as the type.

A number of varieties, developed for cooking at the succulent stage, are smooth-seeded and consequently belong morphologically in the field pea group. Among these are certain early varieties such as Alaska, Electric, Eight Weeks, and Eureka, also the late garden variety Marrowfat—the true variety and not a certain size regardless of variety designated by canners as "Marrowfat"—and the small-seeded French Canner (*petits pois*). In fact the microscopic characters of the starch indicate that all smooth-seeded shell peas, whether grown for the mature seed or for forage on the one hand or for cooking at the succulent stage on the other, belong under *P. arvense* and all wrinkled peas under *P. sativum*. The classification according to color of flower and seed, surface of seed, and height of plant, given by Harz,[1] although instructive, lacks scientific basis.

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[1] Compt. rend. 1906, **143**, 970.

[2] Wicht. Nahr.-Genussm., Berlin, 1899, p. 56.

Smooth varieties, classed as Canada field peas, are grown for the seeds, for forage, and for soiling. Split peas are used for soups, and flattened, roasted peas are a common coffee substitute.

MACROSCOPIC STRUCTURE.—It is a common statement that the *flower* of the field pea is colored while that of the garden pea is white. This is not a universal rule. In the Canada pea, grown by the authors, the flower is white or nearly so. The *pod* and *seed* (Fig. 94) are like those of the wrinkled pea except that the seed is well rounded and free from wrinkles, hence the terms "smooth" or "round." Commonly the seed is buff or green but in some varieties it is brown or dark red.

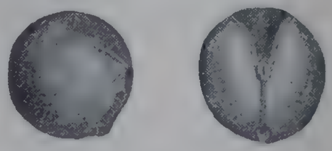

FIG. 94.—Smooth Pea. Seed. × 2. (A.L.W.)

Both smooth and wrinkled peas have the following characters: (1) prominent *funiculus*, often 3 to 4 mm. long, broadened at the end, (2) oval *hilum* with a slit through its longest diameter, (3) *caruncle* and *hilum cushion* absent, (4) *strophiole* consisting of a slight elevation seen under a lens at about one-eighth of the circumference from the hilum slit, (5) *raphe* extending from the hilum and beneath the strophiole to the chalaza, (6) *micropyle* close by the other end of the hilum slit, and (7) outline of the beak-like *radicle*, with its end near the micropyle, showing through the spermoderm.

After removal of the skin, formed by the spermoderm and perhaps traces of the endosperm, the cotyledons are seen to form two hemispheres, somewhat distorted by the short recurved radicle.

MICROSCOPIC STRUCTURE.—Several microscopists, beginning with Pringsheim,[2] have described the structure of the mature pea.

Spermoderm (Figs. 95 and 96).—The three layers are: (1) *palisade cells* (*pal*, *pal*^{1}, *pal*^{2}), or outer epiderm, up to 90 μ high and 20 broad, with a narrow light line (*l*) beneath the thin cuticle; (2) *subepiderm*

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[1] Samenkunde, Berlin, 1885, p. 646 et seq.

[2] Inaug. Dis., Halle, 1845.

(sub, sub^1, sub^2) of cells up to 25 μ high and 50 μ broad, of spool-shape form with ribs more or less evident, especially in surface mounts or after cautious maceration with sodium hydroxide; and (3) *parenchyma* (p, p^1, p^2) of cells which from without inward decrease in size and have increasingly large intercellular spaces.

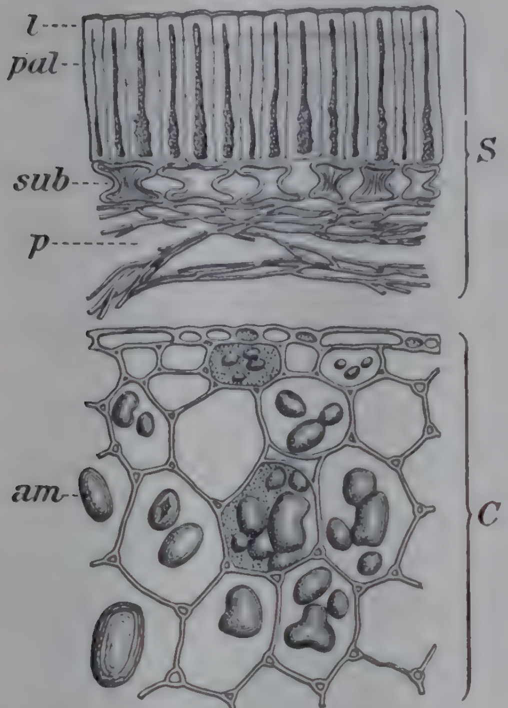

FIG. 95.—Smooth Pea. Seed in cross section. S spermoderm: *pal* palisade cells with l light line; *sub* subepiderm of hour-glass cells; p parenchyma. C cotyledon with *am* starch grains. × 160. (A.L.W.)

The lumen of the *palisade cells* is narrow and smooth in the outer two-thirds, broader and wrinkled in the inner portion.

Beneath the hilum, where as in other legumes the palisade layer is double, the cells surrounding the sclerenchyma group are thick-walled, bone-shaped, and, in the common varieties without colored contents or conspicuous ribs.

Endosperm and Perisperm.—Not evident.

Embryo.—The cotyledons (Fig. 95, C) consist of (1) two *epiderms* of narrow, tangentially elongated cells, often in parquetry-like groups (Fig. 96, C); and (2) a *mesophyl*, throughout of isodiametric, very indistinctly porous-walled cells, with small intercellular spaces at the corners, containing starch grains (*am*), up to 50 μ. The typical grains are aggregates or semi-aggregates

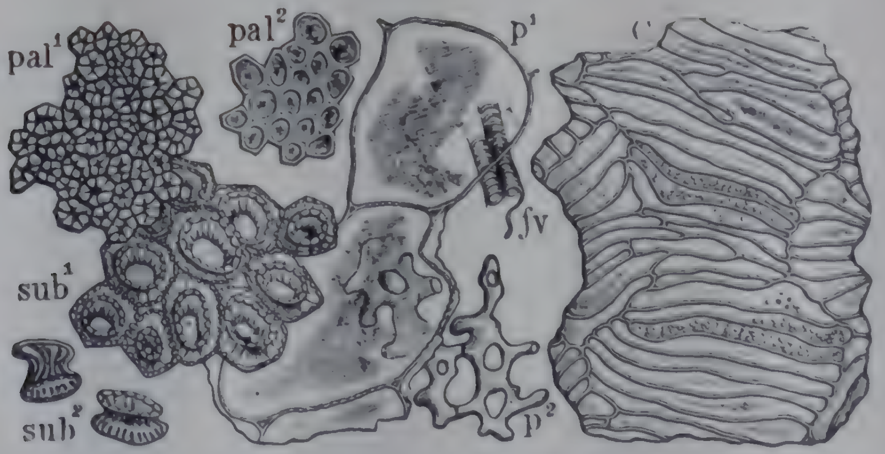

FIG. 96.—Smooth Pea. Elements of seed in surface view. Spermoderm: pal^1 palisade cells seen from above; pal^2 palisade cells seen from below; sub^1 subepiderm (hour-glass cells); sub^2 subepiderm after maceration seen from side; p^1 outer and p^2 inner parenchyma; *fv* fibro-vascular bundle elements. C outer epiderm of cotyledon. × 160. (K.B.W.)

with irregular swellings corresponding to the component grains. At maturity no distinct lines separating the individual grains are evident, although lines may be seen at the earlier stages. Axial rifts such as occur in bean starch (which see) or rifts separating the individual grains such as occur in the starch of the wrinkled garden pea (which see) are unusual.

The crosses formed with polarized light are the best means of distinguishing the individuals. The forms of the aggregates include irregularly ellipsoidal, kidney-shaped, trefoil-shaped, etc.

Chief Structural Characters.—Seed smooth, well rounded; hilum oval; strophiole and micropyle evident under a lens.

Palisade cells up to 90 μ high, with narrow light line and thin cuticle; subepidermal cells, up to 25 μ high, spool-shaped with ribs often evident. Endosperm not evident. Epidermal cells of cotyledons parqueted; mesophyl cells without distinctly beaded walls; starch grains up to 50 μ, half-compound, irregularly rounded, with few rifts. See also table p. 299.

CHEMICAL COMPOSITION.—The analyses reported by Balland[1] and by Atwater and Bryant,[2] given below, doubtless are of smooth peas.

Composition of Dried Peas

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Balland:							
Min.	....	10.60	18.88	1.22	56.21	2.90	2.26
Max.	....	14.20	23.48	1.40	61.10	5.52	3.50
A. and B.:	8						
Min.	....	6.9	20.4	0.8	58.0*	1.2	2.2
Max.	....	15.0	28.0	1.3	64.4*	7.9	4.3
Aver.	....	**9.5**	**24.6**	**1.0**	**62.0***	**4.5†**	**2.9**

* Total carbohydrates. † 2 analyses.

The analyses in König's compilation show a similar range.

Additional results on the composition of peas, as well as beans and vetches, and their products appear in Koehler's monograph.[3]

Schulze, Steiger, and Maxwell[4] made the following extensive analysis of the pea: true protein (total nitrogen, less nuclein and lecithin nitrogen, × 6) 21.50, nuclein (and plastin?) 1.14, glycerides and free fatty acids 1.87, cholesterol 0.06, lecithin 1.21, soluble organic acids 0.73, sucrose and lupeose 6.22, starch 40.49, paragalactoaraban (paragalactan of earlier paper) etc. by difference 17.29, fiber 6.03, and ash 3.46; total 100 per cent.

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[1] Compt. rend. 1897, **125**, 119.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[3] Landw. Vers.-Stat. 1901, **55**, 401.

[4] Ibid. 1891, **39**, 297.

Composition of Large and Small Peas.—Marek[1] notes that the proportion of cotyledons (93.04 per cent) in large peas was higher than in small peas (90.38 per cent) and that the protein was more than 1.5 per cent lower and of fiber more than 2 per cent higher on the same water basis, the other constituents being only slightly different.

Gwallig[2] in more extensive experiments found that in one variety the large kernels had a distinctly higher protein content than the smaller, but in another variety, although in all comparisons but one the advantage was in favor of the large peas, the difference was slight.

Dubois (see Wrinkled Pea), who analyzed fresh green peas of two varieties, one (Alaska) of the field or smooth species, the other (Admiral) of the garden or wrinkled species, of different sizes and presumably degrees of ripeness, was unable to establish any definite relation between size and protein content.

Pea Meal.—Analyses made at New Jersey, New York, Massachusetts, and Wisconsin Experiment Stations from 1885 to 1888[3] show the following average composition: water 10.46, protein 20.23, fat 1.19, nitrogen-free extract 51.10, fiber 14.38, and ash 2.64 per cent.

Pea Hulls.—Analyses of pea hulls, summarized by Böhmer,[4] show as low as 7.1 and do not exceed 8.0 per cent of protein. The average of 2 analyses of pea bran in the compilation of Lindsey, Smith, and Beals[5] is: water 11.0, protein 10.0, fat 1.0, nitrogen-free extract 35.6, fiber 39.7, and ash 2.7 per cent.

Green Peas and Canned Peas.—See Wrinkled Pea.

Proteins.—According to Osborne and Campbell[6] the proteins of the pea, as well as of the lentil, the vetches, the broad (horse) bean, and some other legumes, are: (1) *legumin*, a globulin, the chief protein, (2) *vicilin*, another globulin forming with the legumin about 10 per cent of the seed, (3) *legumelin*, with certain properties of a globulin but more properly classed as an albumin, forming about 2 per cent of the kernel,

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[1] Landw. Vers.-Stat. 1876, **19**, 42.

[2] Landw. Jahrb. 1894, **23**, 835.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11**.

[4] Kraftfuttermittel, Berlin, 1903, p. 320.

[5] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[6] J. Am. Chem. Soc. 1896, **18**, 583; 1898, **20**, 348, 410.

(4) *protoproteose*, and (5) *deuteroproteose*, the proteoses together occurring to the extent of about 1 per cent.

Legumin was discovered by Einhof[1] in peas and beans and was erroneously regarded by Liebig[2] as the same as casein. Ritthausen[3] used at first weak alkali and later salt solution for its extraction, the latter yielding a preparation practically identical with those of Osborne and Campbell obtained fifteen years later.

Legumin is insoluble in water but readily soluble in 2 per cent salt solution although less so in weaker solutions. In 1 per cent salt solution it is sparingly soluble.

Hammarsten[4] designates as *a-legumin* the substance soluble in dilute salt solution which is prepared by dialyzing the salt extract and as *b-legumin* the insoluble substance, apparently an " acid metaprotein," such as was prepared by Ritthausen by precipitation of the alkali extract with acetic acid. This acid compound differs in properties from that formed by *a*-legumin with acids and does not appear to have been formed from *a*-legumin.

Vicilin is insoluble in water. It is much more soluble in salt solution than legumin. The liquid in 10 per cent salt solution becomes turbid at 90° to 95° C. and almost completely coagulated when heated for a time at 100° C. The sulphur content is low—the lowest in any known protein.

Legumelin is soluble in water and coagulable, although no definite point of coagulation can be stated owing to the great influence of salts or acids as well as the proportions of this protein in the solution. Osborne and Harris[5] note the resemblance of legumelin to the leucosin of wheat and regard it as a tissue, not a reserve, protein.

Ultimate Composition.—The results on legumin, vicilin, and legumelin, tabulated on the next page, differ little from those on the corresponding proteins of the lentil, vetch, and broad bean.

Amino Acids of Pea Proteins.—Osborne and Clapp[6] and Osborne and Heyl[7] report results on material prepared by Osborne and Harris using the fractional ammonium sulphate precipitation method[8] as shown in the second table on the next page.

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[1] J. d. Chem. 1806, **6**, 115, 542.

[2] Ann. Chem. Pharm. 1841, **39**, 129.

[3] J. prakt. Chem. 1868, **103**, 65, 193, 273; 1881, **24**, 221; 1881, **26**, 504.

[4] Z. physiol. Chem. 1918, **102**, 85.

[5] J. Biol. Chem. 1907, **3**, 213.

[6] Ibid. 1907, **3**, 219.

[7] Ibid. 1908, **5**, 187, 197.

[8] Ibid. 1907, **3**, 213.

	Ritthausen	Osborne and Campbell				
	Legumin	Legumin	Vicilin	Legumelin	Proto-proteose	Deutero proteos
	%	%	%	%	%	%
Carbon	51.60	52.20	52.36	53.31	50.24	49.66
Hydrogen	6.96	7.03	7.03	6.99	6.76	6.78
Nitrogen	18.26	17.90	17.40	16.30	17.35	16.57
Sulphur	0.33	0.39	0.18	1.06	1.25	1.40
Oxygen	22.48	22.48	23.03	22.34	24.40	25.59

PRODUCTS OF HYDROLYSIS OF PEA PROTEINS

	Legumin	Vicilin	Legumelin
	Osborne and Clapp	Osborne and Heyl	Osborne and Heyl
	%	%	%
Glycocoll	0.38	0.0	0.50
Alanine	2.08	0.50	0.92
Valine	?	0.15	0.69
Leucine	8.00	9.38	9.63
Serine	0.53	?	?
Cystine	....	....	....
Aspartic acid	5.30	5.30	4.11
Glutamic acid	16.97	21.34	12.96
Tyrosine	1.55	2.38	1.56
Phenylalanine	3.75	3.82	4.79
Proline	3.22	4.06	3.96
Tryptophane	+	+	+
Arginine	11.71*	8.91	5.45
Lysine	4.98*	5.40	3.03
Histidine	1.69*	2.17	2.27
Ammonia	2.05*	2.03	1.26
	62.21	65.44	51.13

* Osborne and Heyl.

Jones, Gersdorff, and Moeller[1] obtained the following figures c cystine and tryptophane respectively: legumin 0.83 and 1.76, vicili 0.57 and 0.15 per cent.

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[1] J. Biol. Chem. 1924, **62**, 183.

Fat.—Stellwaag[1] has examined the ether and benzine extracts of peas, beans, and vetch, but some of the more important values such as specific gravity, refractive index, and iodine number were not determined. His results on the field pea follow:

	Melt. pt.	Sapon. No.	Neutral fat	Fatty acids, total	Fatty acids, free	Lecithin	Unsapon. matter
	° C.		%	%	%	%	%
Ether extract . .	below 10	188.90	58.70	87.61	11.32	27.37	7.37
Benzine extract.	" 10	186.50	74.00	87.67	11.95	6.95	8.11

The percentage of lecithin in the fat is abnormally high; nevertheless it represents only about a third of the amount Schulze and Frankfurt[2] found in the whole seed.

Acids.—From the alcohol extract of peas of the Alaska variety Jodidi[3] isolated *citric acid* equivalent to 0.36 per cent on the dry basis.

Carbohydrates.—The percentages of the different groups, as determined in 1891, are given in the general analysis by Schulze, Steiger, and Maxwell above.

Reducing Sugars.—Data on the reducing sugars either in the green or the ripe pea are not at hand. In canned or otherwise cooked peas, the reducing sugars are largely the result of inversion of the sucrose or other non-reducing carbohydrates.

Lupeose, *Stachyose*, and *Paragalactoaraban.*—See Yellow Lupine.

Galactose.—See Common Bean.

Hemicelluloses are abundant in the hulls of peas. Schulze and Pfenninger[4] found 18.4 per cent when unripe and 33.8 per cent when ripe. On hydrolysis of the hemicellulose, they obtained levulose, galactose, and arabinose from the hulls of unripe seeds but only levulose and galactose from the hulls of ripe seeds.

Phosphorus-Organic Compounds. *Lecithin.*—See Fat.

Schulze and Frankfurt[5] found in the ripe and unripe seeds respectively 1.23 and 0.50 per cent of lecithin.

Mineral Constituents.—The percentages of the common ingredients of the ash are shown in the following analysis given by Wolff:[6]

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[1] Landw. Vers.-Stat. 1890, **37**, 135.

[2] Ibid. 1893, **43**, 30.

[3] J. Am. Chem. Soc. 1933, **55**, 4663.

[4] Z. physiol. Chem. 1910, **68**, 93.

[5] Loc. cit.

[6] Aschenanalysen.

Composition of Pea Ash (Wolff)

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
% 43.10	% 0.98	% 4.81	% 7.99	% 0.83	% 35.90	% 3.42	% 0.91	% 1.59

Minor Mineral Constituents.—The results are on both smooth and wrinkled peas.

Iron.—Dried peas 56 to 60 mg. per kilo (Bunge).[1] Dried peas, smooth 48, wrinkled 64 mg. per kilo (Sherman).[2] Peas, Alaska 70, Gradus 138, Telephone 80 mg. per kilo, dry basis (McHargue).[3] Green peas 17.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[4] Green peas, 2 samples, 12.7, 16.8 mg. per kilo, fresh basis (Toscani and Reznikoff).[5]

Blunt and Otis[6] found that the loss of iron on boiling fresh wrinkled peas was 36 per cent of the whole.

Aluminum.—Green peas 3.1 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[7] Green peas 1 mg. per kilo, dry basis (Bertrand and Lévy).[8]

Manganese.—Smooth pea, seeds 11, blooms 21, leaves 38, stems 14 mg. per kilo, dry basis; hay, 6 samples, 20 to 52, aver. **33** mg. per kilo, air-dry basis (Jones and Bullis).[9] Peas 0.4 mg. per kilo, dry basis (Wester).[10] Green peas, Alaska 12, Gradus 14, Telephone 10 mg. per kilo, dry basis (McHargue).[3] Peas 8.3 mg. per kilo, air-dry basis (Quartaroli).[11] Split peas 30.7 mg. per kilo, dry basis (Peterson and Skinner).[12]

Copper.—Wrinkled peas, green, seed 11, pods 9.5; same peas 20 days later, ripe and dry, seed 11, pods 4 mg. per kilo, dry basis (Mcquenne and Demoussy).[13] Peas 7.2 mg. per kilo, fresh basis (Guérithault).[14] Peas 8.8 mg. per kilo, air-dry basis (Quartaroli).[15] Peas, green 2.4, split 14.0 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[16]

Zinc.—Dried peas 34.5 mg. per kilo, air-dry basis (Birckner).[17] Green peas 40.1

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[1] Z. physiol. Chem. 1884–5, **9**, 49.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[3] J. Agr. Res. 1923, **23**, 395.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Nutrition 1934, **7**, 79.

[6] J. Home Econ. 1917, **9**, 213.

[7] Am. J. Physiol. 1929, **90**, 72.

[8] Bul. soc. hyg. aliment. 1931, **19**, 359.

[9] J. Ind. Eng. Chem. 1921, **13**, 524.

[10] Biochem. Z. 1921, **118**, 158.

[11] Ann. chim. appl. 1928, **18**, 47.

[12] J. Nutrition 1931, **4**, 419.

[13] Compt. rend. 1920, **170**, 87.

[14] Bul. soc. hyg. aliment. 1927, **15**, 386.

[15] Ann. chim. appl. 1928, **18**, 47.

[16] J. Biol. Chem. 1929, **82**, 465.

[17] Ibid. 1919, **38**, 191.

to 51.7 mg. per kilo, dry basis (Hubbell and Mendel).[1] Peas 44.5 mg. per kilo, air-dry basis (Bertrand and Benzon).[2]

Arsenic.—Seeds 0.26 mg. per kilo (Jadin and Astruc).[3]

Iodine.—Seeds none (Winterstein).[4] Leguminous seeds less than 1.5 mg. per kilo (Bohn).[5]

Boron.—Peas absorb a relatively large amount from the soil (Cook).[6]

WRINKLED PEA

Pisum sativum L.

The taxonomy of wrinkled and smooth peas, both of which are used as green seed vegetables, is discussed in the preceding section. Probably a native of western Asia, this vegetable appears to have been carried to Europe as early as the time of the Lake Dwellers. It is now grown the world over.

In the canning industry the whole plant is cut, the seeds being separated and graded according to size by a machine known as the viner. The smaller sized and more delicate seeds, in the same lot and variety, are less mature than the larger. Size of peas, however, is not a universal criterion of development since in some varieties the mature pea is small. Soaked mature peas are canned to some extent.

MACROSCOPIC STRUCTURE.—Passing by the variations in size and shape, the characters of the *pod* common to all varieties are: (1) the tendency to curve outward on the dorsal edge, (2) the short blunt point, (3) the conspicuous dehiscence slit on the ventral (suture or seed-bearing) edge between the ribbed margins of the carpellary leaf, (4) the midrib on the dorsal edge, and (5) the reticulated veining. Except for the wrinkles the *seed* is like that of the smooth pea.

MICROSCOPIC STRUCTURE.—The statements made herewith are based on an examination of mature seeds of the following representative wrinkled varieties grown in the United States, arranged approximately according to height, beginning with the lowest: Bliss' American Wonder, Sutton's Excelsior, Nott's Excelsior, Burpee's Blue Bantam, Little Gem, Laxtonian, Advancer, Gradus, Yorkshire Hero, Bliss' Everbearing, and Telephone.

Spermoderm.—Structure as in smooth pea.

Embryo.—As in the smooth pea, the cell walls of the cotyledon are very indistinctly porous. Of eleven varieties named above, one (Blue Bantam) agrees with the smooth pea in having numerous semiaggregate *starch grains* (usually mistaken for simple grains); the remaining ten have true aggregates, differing from semiaggregates in that (1) they are more irregular in shape with more pronounced rounded excrescences, (2) they show rifts and lines of separation between the component grains, and (3) the individuals sometimes separate from the aggregates. Polarizing apparatus serves to bring out the individuals of the aggregates, although the polarization of the immature grains is weak and the presence of the rifts often obscures the crosses.

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[1] J. Biol. Chem. 1927, **75**, 567.

[2] Bul. soc. hyg. aliment. 1928, **16**, 457.

[3] Compt. rend. 1912, **154**, 893.

[4] Z. physiol. Chem. 1918, **104**, 54.

[5] J. Biol. Chem. 1917, **28**, 375.

[6] J. Agr. Res. 1916, **5**, 877.

The character of the *starch grains* in immature smooth peas is much like that in mature wrinkled peas. This suggests that the wrinkled pea, although fertile, is either gathered when immature or is incapable of reaching the same degree of development as the smooth variety. The wrinkles on the kernels also suggest underdevelopment. The same logic applies to sweet corn, which has partially developed starch grains and wrinkles on the kernels.

CHIEF STRUCTURAL CHARACTERS.—Seed deeply wrinkled, otherwise as in smooth pea.

Cell structure like that of smooth pea at the same stage of development. Starch grains in true aggregates. See also table p. 299.

CHEMICAL COMPOSITION. Green Peas.—Atwater and Bryant[1] report an average of 45 per cent of pod in the unshelled peas and the range and average composition of the kernels as shown in the table which follows:

	Water	Protein	Fat	N-f. ext.*	Ash
	%	%	%	%	%
Min.	71.6	4.4	0.3	13.4	0.9
Max.	78.1	8.0	0.6	18.9	1.2
Aver.	**74.6**	**7.0**	**0.5**	**16.9***	**1.0**

* Includes fiber.

Bitting,[2] incidental to descriptions of canning processes, reports analyses of shelled peas separated into three grades for size, known as petits pois, sifted, and marrowfat, irrespective of horticultural variety, and into three sub-grades for quality as determined by density. First quality peas float in salt solution of specific gravity 1.04; second quality float, and third quality sink, in salt solution of specific gravity 1.07.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Ibid. Bur. Chem. 1909, Bul. **125**.

Composition of Peas Graded for Size and Quality (Bitting)

Grade	Solids	Protein	Sucrose*	Starch	Pentosans	Fiber	Ash	Undetermined
	%	%	%	%	%	%	%	%
Petits pois:								
First........	14.23	3.44	0.72	5.57	0.75	1.68	1.03	1.04
Second......	18.80	4.19	0.93	8.53	0.92	1.84	1.78	0.61
Third.......	18.44	4.41	0.82	8.53	0.94	2.28	1.82	0.36
Sifted:								
First........	22.06	5.31	0.99	10.23	0.96	2.21	1.36	1.01
Second......	24.32	5.69	0.57	11.52	1.01	2.05	1.04	2.44
Third.......	27.74	5.63	0.48	13.52	1.50	2.18	1.37	3.06
Marrowfat:								
First........	22.22	5.13	0.94	10.48	0.98	2.18	1.02	1.49
Second......	24.10	6.69	0.64	8.77	1.55	2.55	1.30	2.60
Third.......	27.15	5.94	0.36	12.91	1.27	2.00	2.03	2.64

* No reducing sugars were found in any of the samples.

It is well known that green peas, soon after picking, lose their sweetness. Kertesz[1] found that a decrease in sucrose was accompanied by an increase in alcohol-insoluble matter.

Numerous analyses made at the New York Agricultural Experiment Station[2] led to the following tentative maximum limits for high-grade canning peas: puncture value 40 g. per sq. mm., starch-sugar ratio 1, insoluble-soluble nitrogen ratio 3, CaO in fresh skins 0.06 per cent.

Changes in Composition During Growth.—Bisson and Jones,[3] in commenting on their analyses of shelled peas at different stages of development (given in the following table on the dry basis), state that green peas are ready for harvest when the absolute weight of sucrose has reached the maximum, which is somewhat later than when the percentage is highest; protein, starch, fiber, and ash, however, increase in absolute amount throughout growth.

Age	Solids, fresh basis	Protein	Sugars, total *	Sugars, reducing *	Sucrose	Starch	Polysaccharides †	Fiber	Ash
days	%	%	%	%	%	%	%	%	%
12	16.66	32.25	27.74	0.53	25.84	16.33	4.27‡	1.93	3.98§
32	25.51	24.87	21.55	....	20.47	19.13	11.71	8.55	3.62
48	68.80	24.69	9.10	0.09	8.56	26.63	11.15	7.62	3.77

* As invert. † Other than starch; acid hydrolyzable. ‡ 18 days. § 20 days.

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[1] Plant Physiol. 1930, **5**, 399. [2] Rep. 1930, p. 50. [3] Plant Physiol. 1932, **7**, 91.

Changes in Composition During Storage.—The figures reported b Jones and Bisson[1] throw light on the loss of sweetness of peas aft picking. The loss in the kernels of sucrose and starch, which was mo rapid at 25° C., was almost entirely prevented by storing at 0° C. I the pods, the reducing sugars remained constant at 0 to 5° C., bu decreased at higher temperatures; sucrose and starch decreased at a temperatures, the loss of sucrose being most rapid at 35° C.

Canned Peas.—Bitting[2] states that in the United States canne peas rank third in output, tomatoes and green corn being respectivel first and second, although in point of money value peas rank secon Six grades according to size are recognized by the trade, the name which do not represent horticultural varieties, being (1) " petits pois, (2) " extra sifted " or " extra fins," (3) " sifted " or " fins," (4) " earl June," (5) " marrowfats," and (6) " telephone peas." Peas are packe in No. 2 cans which hold on the average 400 grams of peas and 200 gram of liquor.

The composition of the total contents of the can including liquor a determined by McElroy and Bigelow[3] and Street[4] is tabulated below:

Composition of Canned Peas Including Liquor

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash*	Salt
		%	%	%	%	%	%	%
McE. and B.:	81							
Original	....	85.48	3.56	0.21	8.46	1.18	0.45	0.66
Water-free	....	....	24.52	1.45	58.26	8.13	3.09	4.55
Street:	111							
Original	....	85.37	3.51	0.29	8.61	1.13	0.43	0.66
Water-free	....	....	24.00	1.98	58.85	7.72	2.94	4.51

* Peas only.

Drained Peas.—Ordinarily only the drained peas from the can ar eaten, the liquid being rejected, although in cooked peas fresh from th garden the liquor is prized for its sweetness and delicate flavor.

Dubois,[5] in an investigation of peas for canning and of (drained canned peas, analyzed samples of four series representing two varieties one smooth (Alaska) the other wrinkled (Admiral), two localities o production, and five grades or sizes. The average results of analyses of grade 1 and of grade 5 for the two localities appear below:

---

[1] Plant Physiol. 1932, **7**, 273.

[2] Loc. cit.

[3] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, Part 8, 1094.

[4] Connecticut Agr. Exp. Sta. Rep. 1910, p. 456.

[5] U. S. Dept. Agr., Bur. Chem. 1910, Circ. **54**.

Composition of Fresh and Canned Peas (Dubois)

(Results on dry basis)

	Solids, fresh basis	Protein	Fat	Starch	Fiber	Ash
	%	%	%	%	%	%
Alaska:						
Fresh, No. 1....	19.69	29.31	1.51	33.76	9.59	4.06
" No. 5....	34.82	26.00	1.35	51.38	7.51	3.01
Canned, No. 1....	14.22	....	....	41.26	11.43	6.63
" No. 5....	26.30	....	....	55.62	8.50	3.73
Admiral:						
Fresh, No. 1....	19.99	32.69	1.01	35.42	9.27	4.48
" No. 5....	23.06	30.44	1.72	44.81	11.07	3.85
Canned, No. 1....	14.04	....	....	39.03	12.52	7.57
" No. 5....	19.77	....	....	58.69	12.04	5.39

Street[1] found the weight of drained peas per can to vary from 211 to 455 grams and the composition as shown below:

Composition of Drained Peas (Street)

	Water	Protein	Fat	N-f. ext.	Sugars, reducing*	Starch	Fiber	Ash†	Salt
	%	%	%	%	%	%	%	%	%
Original:									
Min....	72.83	2.52	0.14	4.75	0.34	2.04	0.94	0.30	0.09
Max....	90.46	6.45	0.85	18.58	5.18	15.65	2.08	0.78	1.12
Aver....	**80.86**	**4.62**	**0.46**	**11.23**	**2.26**	**7.64**	**1.77**	**0.48**	**0.58**
Water-free:									
Min....	....	18.43	0.77	49.75	1.37	21.38	7.12	1.77	0.46
Max....	....	30.86	4.24	68.38	28.71	59.78	11.91	3.45	6.67
Aver....	....	**24.14**	**2.40**	**58.67**	**11.81**	**39.92**	**9.25**	**2.51**	**3.03**

* As dextrose. † Peas only.

In experiments by Kertesz and Green[2] peas quickly cooled, especially if blanched at 82° C. (180° F.) before cooling, showed no deterioration during several days if kept at −1° C. (30° F.). The blanching completely checked a loss in sugar which takes place during cold storage.

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[1] Loc. cit.

[2] J. Agr. Res. 1932, 45, 361.

Soaked Peas.—In 16 of Street's samples the high starch content, thick liquor, hardness and prominence of the cotyledons, and low water content indicated that either soaked dried peas or over-mature peas had been used.

Liquor.—Street found that the liquor made up from 27 to 49.7, aver. **36.1** per cent of the total weight of the contents of the can. It contained on the average 16 per cent of the total solids in the can, 10 per cent of the starch, and 16 per cent of the protein of the original peas. The salt, sugar (sucrose), and sometimes glucose of the liquor are added in different proportions by the canner for flavor. Some canners use nothing but water. A certain small amount of the added liquor penetrates into the kernel, on the other hand soluble nitrogenous, saccharine, and mineral constituents are extracted.

Proteins.—Data by Muttelet[1] show that the percentage of insoluble crude protein, which is less than that of the soluble, including amides, in the small and very immature kernels, increases on ripening until full maturity is reached when it is double that of the soluble protein.

Fat.—In several of the foregoing tables the percentages of fat are given. In addition to true fat, the so-called fat (ether extract) of green peas contains green coloring matter. Further information as to its nature is not available.

Acids.—Ritthausen[2] isolated *citric acid*; Jodidi[3] reports in the Alaska variety 0.36 per cent, dry basis.

Carbohydrates.—*Sugar*, *starch*, and *cellulose* at different stages of ripeness have been determined by Muttelet[1] with the following results:

	Small	Medium	Full-grown green	Full-grown ripe	Canned
	%	%	%	%	%
Sugars..........	6.70	6.20	5.90	4.10	7.10
Starch..........	27.30	32.40	32.90	43.40	31.50
Cellulose........	11.30	11.50	9.60	7.40	10.10

In a foregoing table credited to Bitting, results on sucrose, starch, and pentosans are given.

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[1] Compt. rend. 1925, **180**, 317.

[2] J. prakt. Chem. 1884, **29**, 357.

[3] J. Am. Chem. Soc. 1933, **55**, 4663.

The nature of the sugars and insoluble carbohydrates is discussed under Smooth Pea.

Bourdouil[1] crossed smooth peas, containing 33 to 34 per cent of starch, with wrinkled peas, containing 18 to 21 per cent. The seeds of the hybrid were smooth, containing 32 to 38 per cent of starch.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[2] found 5.31 per cent, dry basis.

Minor Mineral Constituents.—See Smooth Pea.

EDIBLE-PODDED PEA

Pisum sativum L. sub-sp. *gullosum* Risso = var. *saccharatum* Hort.

Fr. Pois goulus. Ger. Zuckererbse.

The sugar or edible-podded pea bears the same relation to the shell pea as the snap bean does to the shell bean. Harz[3] divided the subspecies into two varieties, each with white- and colored-flowered subvarieties: *macrocarpum* Sering (sword sugar pea) with pods 11.5 cm. long and 2.4 to 2.7 cm. between the two edges and *saccharatum* Sering (common sugar pea) with pods 7.25 cm. long and 1.44 cm. between the two edges.

MACROSCOPIC STRUCTURE.—Although the *pods* at maturity are still flattened in the dorsal portion, the seeds being restricted to the ventral edge where, distending the pod, they appear like a string of beads, the pods are in best condition for eating at an earlier stage of development. The ventral edge is nearly straight, the dorsal edge strongly bowed outward. The *seeds* at maturity are wrinkled and variously spotted or mottled with brown in the varieties studied.

MICROSCOPIC STRUCTURE. Pericarp.—As in the snap bean, there are six layers but the fourth and fifth are not analogous: (1) *epicarp* of thin-walled cells tangentially elongated and diagonally arranged, excepting the groups of small isodiametric cells about the numerous stomata; (2) *hypoderm* of somewhat elongated, only slightly collenchymatous cells; (3) *mesocarp*, forming the bulk of the pod, of large, rounded, loosely arranged cells containing chlorophyl grains and clusters of rounded starch grains up to 22 μ, sometimes in twins and triplets; also fibro-vascular bundles; (4) *crystal layer* of isodiametric cells each with an oxalate crystal; (5) thin *fiber layer*, more or less sclerenchymatized according to the ripeness: and (6) *endocarp* of thin-walled cells, isodiametric in surface view, each protruding into the pod cavity as a papilla or blunt, thin-walled, unicellular or jointed hair, containing throughout numerous chlorophyl grains.

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[1] Bul. soc. chim. biol. 1933, **15**, 790.

[2] Philippine Agr. 1932, **21**, 53.

[3] Samenkunde, Berlin, 1885, p. 646.

An incrustation of *wax* on the cuticle of the epicarp gives the pod its peculiar glaucous appearance.

Spermoderm.—At the edible stage the tissues are undeveloped. At full maturity the structure differs from that of the common pea in that pigment is present in the *palisade cells.*

Embryo.—The *starch* of the mature seed resembles that of the smooth pea.

Chief Structural Characters.—Outer tissues more characterless than those of snap bean; epicarp without hairs; hypoderm not collenchymatous. Crystal cell layer, in addition to crystal cells near the string, present; endocarp with numerous papillæ and thin-walled, blunt, unicellular or jointed hairs. Starch at maturity like that of smooth pea.

CHEMICAL COMPOSITION.—Chung and Ripperton[1] give the following analysis of a green, edible-podded pea known in Hawaii by the Chinese name *hoh-lang-dau* and the Japanese name *chabo-endo:* water 88.66, protein 3.33, fat 0.10, nitrogen-free extract 6.10, fiber 1.06, and ash 0.75 per cent.

Mineral Constituents.—The authors named above found: calcium 0.043, iron 0.0032, and phosphorus 0.062 per cent; also alkalinity of the ash 8.2 expressed as cubic centimeters of normal acid per 100 grams of fresh vegetable.

CHICK PEA

Cicer arietinum L.

Fr. Pois chiche. Sp. Garbanzo. It. Cece. Ger. Kichererbse.

Some have thought that the name chick pea was given this legume because of the strong resemblance of the seed to the head of a chick, but the evidence favors the opinion that it is a corruption of *cicer,* the Latin name. According to De Candolle it is probably a native of regions south of the Caucasus and Caspian Sea, where it has been cultivated since prehistoric times. It was early introduced into India, its name according to Narayana[2] being in Sanskrit *chenata,* in Hindi *chana,* and in English *Bengal gram,* and somewhat later into all the Mediterranean countries. From Spain it was introduced into Spanish colonies. The seeds are eaten boiled or roasted and in the latter form also are used as a substitute for coffee.

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[1] Hawaii Agr. Exp. Sta. 1929, Bul. 60.

[2] J. Indian Inst. Sci. 1930, 13A, 153.

MACROSCOPIC STRUCTURE.—The chief characters distinguishing the *plant* from that of the common pea are the glandular hairs and the presence of a terminal leaflet instead of a tendril. The *flowers* are white or purplish. The two upper of the five calyx lobes form a lip; the wings of the corolla are free from the keel; the style is incurved and naked.

In the characters of the *seed* (Fig. 97), it differs widely from its near relatives the pea and the lentil: (1) the seed is irregular in shape, and the surface, in addition to being wrinkled, has a prominent beak marking the position of the nearly straight radicle, (2) the hilum adjoining this beak is small (less than 2 mm.) and margined, with only the barest trace of accompanying caruncle or cushion, and (3) the strophiole is about 3 mm. from the hilum. The common variety has a buff ("white") seed, but there are red-, brown-, and black-seeded varieties. Some varieties have seeds up to 1.5 cm., others up to hardly half that size.

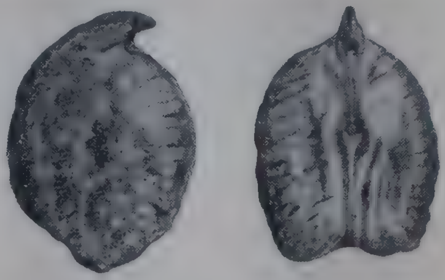

FIG. 97.—Chick Pea. Seed. ×2. (A.L.W.)

MICROSCOPIC STRUCTURE. (Fig. 98).—Several of the treatises briefly describe the structure of the seed. M. Kondo[1] studied seeds of four varieties: (1) small brown Indian, (2) small red-brown German, (3) small yellow Russian, and (4) large yellow Spanish. The writers examined white and red-brown seeds.

Spermoderm (*S*).—The three layers, of which the first is characteristic, are (1) *palisade cells* (*pal*) of irregular height up to 160 μ and up to 20 μ broad, often bent toward the upper ends and rounded at the tips, with thick walls at both ends; (2) *subepiderm* (*sub*) of spool-shaped cells, up to 35 μ high and 35 μ broad, not evidently ribbed; and (3) *parenchyma* with large cells and small intercellular spaces in the outer portion, still larger cells in the middle portion (p^1), and small cells and relatively large intercellular spaces forming a stellate spongy parenchyma in the inner portion (p^2).

As noted by Kondo,[1] the walls of the outer portion in red-brown seeds are strongly thickened with a broad light line, the pigment being present in the middle and inner portion.

Beneath the hilum, the irregularly shaped cells about the sclerenchyma group are colorless with thickened walls and marked intercellular spaces.

Endosoperm (*E*).—Inconspicuous, of a single layer of cells.

---

[1] Z. Unters. Nahr.-Genussm. 1913, **25**, 40.

Embryo.—The *epiderms* (*ep*) of the cotyledons
diametric cells, the *mesophyl* of somewhat porou
beneath the inner epiderm, somewhat radially el
outer, but in r
The *starch gra*
(in red-brown
smaller), are c
Elongated sem
a longitudinal
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CHIEF ST
TERS.—Seeds
hilum at base
mm. from hilu

Palisade c
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35 μ. Endo
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CHEMICA
—In the table
analyses by
Narayana,[3] a
peas grown
Bulgaria, India, and the Philippines, also a sum

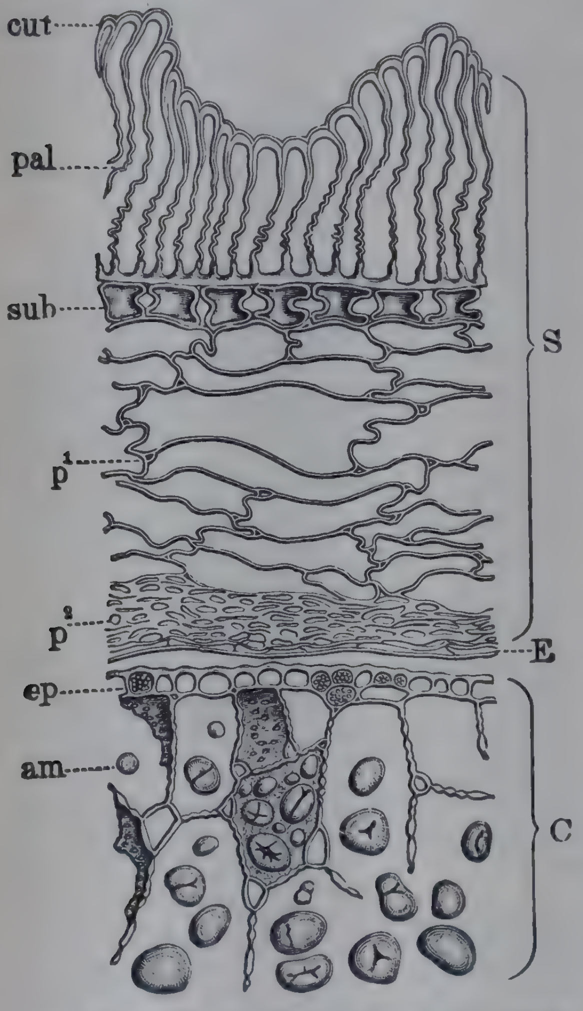

FIG. 98.—Chick Pea. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle, *sub* subepiderm, p^1 outer and p^2 inner spongy parenchyma. *E* endosperm. *C* cotyledon. *ep* outer epiderm, *am* starch grains of mesophyl. × 160. (K.B.W.)

the first in the table appear in subsequent

POSITION OF CHICK PEAS

rotein	Protein, pure	Fat	N-f. ext.	Starch	Fiber	Ash
%	%	%	%	%	%	%
22.47	....	4.49	54.55*	45.05	1.47	2.83†
20.87	....	6.30	....	50.32	3.62	2.87
19.10	16.20	4.16	52.29	44.89	2.40	2.36
27.05	24.10	6.10	59.25	52.80	4.60	4.30
22.62	**20.58**	**5.08**	**56.14**	**49.33**	**3.09**	**2.88**
28.14	25.04	4.72	63.56	....	1.13	2.45
19.94	....	5.38	55.93	....	2.26	2.86
23.80	....	5.20	56.24	....	1.62	2.00
26.10	....	7.00	59.23	....	3.15	3.43
24.77	....	**6.09**	**57.99**	....	**2.21**	**2.73**

s 3.14, pectin, etc. 6.36%. † Pure ash.

Distribution in Seeds.—Zlataroff[1] gives the fol-
ulated to the dry peas: protein nitrogen 2.11,
mmonia nitrogen 0.10, peptone nitrogen 0.007,
nino nitrogen 0.12, and other forms of nitrogen
al nitrogen 3.24 per cent.

nce of the chick pea from other legumes, observed
ation in protein content attributable to soil and
12.3 to 31.5 per cent was noted, the lowest being
odule bacteria.

hick Pea Globulin.—The water- and ash-free
cent of nitrogen and 0.35 per cent of sulphur,
yana,[3] was found by the same author to contain

%		%
	Arginine (direct)	12.09

Nitrogen Distribution in Chick Pea Globulin.—The averages of results, all in terms of nitrogen, by Narayana[1] follow: acid-insoluble melanin 0.37, soluble melanin 0.32, amide 10.42, cystine 0.25, arginine 19.31, lysine 8.49, histidine 1.56, amino 58.23, non-amino 0.44; total 99.39 per cent.

Nitrogenous Bases.—*Betaine* and *choline*, together amounting to 0.02 per cent, were found by Zlataroff.[2]

Fat.—Values of the ether extract, as determined by Nikoloff and given by Zlataroff and Stoikoff,[3] follow: specific gravity at 15°C. 0.9369 to 0.9376, refractive index at 25°C. 1.4744–7, solidification point —19.5°C., saponification number 240, iodine number 110 to 119, Reichert-Meissl number 4.51, Polenske number 1.1, Hehner number 91.6, ester number 239.5, melting point of fatty acids 25°C., iodine number of fatty acids 129, acid number 0.3 to 0.5, and unsaponifiable matter 0.48 per cent.

Sterol.—Zlataroff[2] reports the presence of *slanutosterol*, forming 0.3 per cent of the fat. The acetate of the sterol melts at 128°C.

Acids.—Zlataroff[2] identified *oxalic* and *citric acids* by their lead salts. The soluble oxalate was equivalent to CaO 0.002, the insoluble to 0.005 per cent.

Phosphorus-Organic Compounds.—Zlataroff and Stoikoff[3] found the following percentages of lecithin in chick pea and in *Lebleliji* respectively: in the ether extract 0.11 and 0.64, in the alcohol extract 1.32 and 1.04; total 1.43 and 1.68 per cent.

Ivanoff,[4] quoted by Zlataroff and Stoikoff, found the following average amounts of phosphoric acid in different forms in 4 samples of chick peas: protein P_2O_5 0.452, lecithin P_2O_5 0.125, inorganic and inosite P_2O_5 0.290, and total P_2O_5 0.867 per cent.

Zlataroff,[2] in the sample in which he determined the forms of nitrogen, found protein P_2O_5 (Ivanoff method) 0.486, lecithin P_2O_5 (Schulze method) 0.142, soluble organic P_2O_5 (Ivanoff method) 0.244, and inorganic P_2O_5 (Ivanoff method) 0.118; total P_2O_5 (Neumann method) 0.998 per cent.

Phytin.—Seeds of the varieties *album* and *fuscum*, grown in Spain and analyzed by Miró and Bustinza,[5] contained 0.88 and 0.995 per cent respectively of phytin.

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[1] Loc. cit.

[2] Loc. cit.

[3] Loc. cit.

[4] Die Phosphorstoffe, 1906, pp. 6, 10.

[5] Anal. soc. expañ. fís. quím. 1932, 30, 673.

Mineral Constituents.—The composition of the ash as determined by Passerini[1] follows:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%
24.60	1.29	4.45	19.98	2.42	39.56	3.38	2.85	0.71

Minor Mineral Constituents. *Manganese.*—Seeds 16.6 mg. per kilo, air-dry basis (Quartaroli).[2]

Copper.—Seeds 10.12 mg. per kilo, air-dry basis (Quartaroli).[2]

CHICKLING VETCH

Lathyrus sativus L. = *Cicercula alata* Moench

Fr. Gesette. Ger. Platterbse.

Originally confined to western Asia, this species has long been cultivated as a seed vegetable and fodder plant in central and southern Europe. The sweet pea (*L. odorata* L.) is an ornamental species of the same genus.

Several authors of treatises, beginning with Harz, briefly note the structure of the seed. Kondo[3] describes in detail the morphology and histology of six samples, two designated *Indische Futtererbsen* (Indian fodder peas) and four *Weisse bezw. gelbe Platterbsen* (white or yellow flat peas), the article being illustrated by five cuts. The following description is based on Kondo's results.

MACROSCOPIC STRUCTURE.—*Seeds* of the Indian varieties are axe-shaped, yellow-brown, brown, or black, much mottled or spotted, 3.5 to 5 mm. long and broad, and 3 to 4 mm. thick, with an elliptical brown-bordered yellow-brown hilum 1.2 to 1.5 mm. long on the part corresponding to the back of an axe near one corner, a brown strophiole about 3 mm. from the hilum, and a distinct black raphe; seeds of the yellow varieties are yellowish, axe-shaped, with well-rounded corners, 0.6 to 1.5 cm. long, 0.75 to 1.2 mm. broad, and 0.4 to 0.6 mm. thick, with hilum and strophiole closer together than in the Indian varieties.

MICROSCOPIC STRUCTURE. Spermoderm.—The *palisade cells* are rounded at the outer ends with a cuticle. They range in Indian seed up to 89 μ high and 12 μ broad, with the light line 17 μ from the outer ends; and in yellow seed up to 82 μ high and 17 μ broad, with the light line 24 μ from the outer ends. In the outer part (17 to 28 μ) the palisade cells of all varieties have narrow lumens about which the walls are made up of thick, straight strips; in the middle part (35 to 59 μ) they have thinner but porous walls, appearing wavy in cross section of the spermoderm; in the inner part (17 μ) they have still thinner walls which are non-porous.

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[1] Loc. cit.

[2] Ann. chim. appl. 1928, **18**, 47.

[3] Z. Unters. Nahr.-Genussm. 1913, **25**, 1.

The *subepidermal cells*, in Indian seed, are spool-shaped, ribbed, up to 35 μ high and 47 μ broad. In yellow seed, particularly those of small size, they are somewhat lower but of the same breadth. Several rows of *spongy parenchyma* and a layer of *compressed parenchyma* form the remainder of the tissues over the body of the seed. Beneath the hilum slit is a typical sclerenchyma group, surrounding which and beneath the double palisade layer the parenchyma cells are rounded with rather thick, ribbed walls.

Embryo.—The cells of the *outer epiderm* of the cotyledon are as broad as high and of the *inner epiderm* considerably broader. Palisade cells are lacking. The *starch grains* are of the pea type and range in length up to 43 μ in Indian seeds, 45 μ in small yellow seeds, and 71 μ in large yellow seeds. See also table p. 299.

CHIEF STRUCTURAL CHARACTERS.—Seed axe-shaped, yellow, brown, or black; dark seed spotted or mottled; hilum near one corner on same edge as strophiole but not adjacent.

Palisade cells of spermoderm up to 89 μ high and 17 μ broad, porous in middle portion, with light line 17 to 24 μ from apex; subepidermal cells spool-shaped, ribbed, up to 35 μ high and 47 μ broad. Starch grains of pea type up to 71 μ long. See also table p. 299.

CHEMICAL COMPOSITION.—Two analyses by Pott[1] and one by Hughes[2] are given below:

COMPOSITION OF CHICKLING VETCH

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Pott:						
Cherson, Russia	11.01	27.14	1.88	53.04	3.87	3.06
Jekaterinoslow, Russia	11.80	24.31	1.98	56.43	3.11	2.37
Hughes	11.20	28.29	1.70	49.32	6.73	2.76

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[1] Landw. Vers.-Stat. 1872, **15**, 217.

[2] Analyst 1895, **20**, 169.

Holmes[1] condemns the custom of allowing 15 per cent of the seed of chickling vetch in " Indian peas " used as horse feed, often added because of their cheapness and rich protein content, since they contain a cumulative poison causing paralysis in man and beast. Mirande[2] attributes the injurious action of the seed to autofermentation that takes place in the ground (not the whole) seed at 35 to 40° C. with liberation of carbon dioxide and hydrogen sulphide. The substance that suffers this decomposition is located in the cotyledons and is completely soluble in water. Other common legumes, such as the pea and bean, were shown to undergo the same autofermentation but apparently not to so great an extent.

COMMON BEAN

(String and Shell Beans)

Phaseolus vulgaris Metz. = *P. vulgaris* L. + *P. nanus* L.

Fr. Haricot. Sp. Frijole. It. Fagiola. Ger. Bohne.

Wittmack,[3] in his investigations of seeds of Peruvian tombs, found a number which he identified as varieties of *P. vulgaris* and obtained evidence so conclusive as to convince De Candolle that the species is of South American origin. It is not surprising that much doubt long existed as to the original habitat of a plant with so many marked and widely distributed varieties. Martens[4] gives Latin names to 123 distinct varieties under 7 race groups or sub-species as follows: *P. vulgaris* Savi, *P. compressus* Savi, *P. gonospermus* Savi, *P. carinatus* Martens, *P. oblongus* Savi, *P. ellipticus* Martens, and *P. sphæricus* Martens. More recent writers give even more, not including the numerous horticultural varieties continually being introduced.

String (*Snap*) *Beans*, that is garden varieties developed for edible pods, are of two common groups: (1) green-podded and (2) yellow-podded or wax. By breeding, the " strings " have been so reduced as warrant the name " stringless."

Shell Beans.—In America the commonest dry shell beans, used especially for baked beans or canning, are white, either large (marrowfat) or small (navy or pea), although red kidney beans are also popular.

MACROSCOPIC STRUCTURE.—The *flower* is commonly white, white tinged with green, yellow, or purple, or else a decided violet or purple. The calyx is thin and inconspicuous with the division between the two upper lobes indistinct. As in the whole genus, the keel of the corolla, as well as the style within it, is coiled. The style is bearded along the inner side; the standard is more or less reflexed.

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[1] Pharm. J. 1913, **90**, 795.

[2] Compt. rend. 1921, **172**, 1142, 1202.

[3] Sitzgsb. bot. Ver. Brandenberg. Dec. 19, 1879.

[4] Gartenbohnen, 1869.

The *pod* varies from straight to much curved and the terminal point from short to long. When young it is soft and downy, later it becomes harsh and rough-hairy. The outer mesocarp, when in condition for eating as a snap bean, as seen in cross section, is 1 to 2 mm. thick, light green (green podded) or pale yellow (wax), of uniform density except for a faint line toward the inner side formed by the row of fibro-vascular bundles, while the inner mesocarp is thicker, colorless, turgescent, nearly or entirely filling the space around and also between the seeds. When beyond the snap bean stage, the pod shrinks until finally it becomes thin and dry, the seeds being surrounded by a considerable air space.

The *seed* (Fig. 99) varies from ovoid, approaching spherical, to elongated kidney-shaped and is commonly more or less flattened. The funiculus is short and thick. Compared with the pea, the oval hilum (*H*), with a small caruncle and cushion, has an indistinct slit while the strophiole (*S*), with its two humps, is more prominent. From the strophiole the short raphe (*R*) may be traced to the indistinct chalaza, while near the other end of the hilum the micropyle (*M*) is evident in a slight depression. Unlike that of the pea, the form of the short radicle is not generally noticeable on the surface. As in other members of the genus, the cotyledons are carried above ground on germinating.

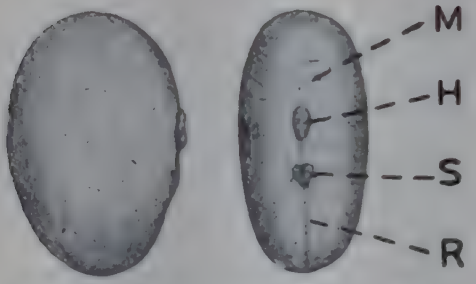

FIG. 99.—Common Bean. Seed. *M* micropyle; *H* hilum; *S* strophiole; *R* raphe leading to chalaza (not shown). × 2. (A.L.W.)

MICROSCOPY OF STRING BEAN.—Well-bred varieties yield pods that are edible when they have reached their full length but not their full thickness.

Pericarp.—The six layers at the latter stage, as seen in surface view (Fig. 100), are as follows: (1) striate-cuticularized *epicarp* (*epi*) of isodiametric or somewhat elongated cells, often with beaded walls, interspersed with hooked (t^1) and straight unicellular hairs (t^2), capitate hairs with multicellular heads (t^3), and stomata; (2) *hypoderm* (*col*) of elongated collenchyma cells, several thick; (3) *outer mesocarp* (p^1) of spongy parenchyma containing scattered small starch grains and in green varieties numerous chlorophyl grains, also in the inner portion a row of fibro-vascular bundles; (4) diagonal *fibers* (*f*), one or more thick; (5) *inner mesocarp* (p^2) of thin-walled parenchyma with no visible contents, interspersed with small crystal cells, often in groups; and (6) *endocarp* (*iep*) of polygonal cells.

Both the straight and the hooked *hairs* have a small basal cell, which in the latter case is constricted, and arise from a circular cell provided with short sprocket-like extensions.

The *fibro-vascular bundles* running through the outer mesocarp are small on the sides of the pod, but at the dorsal and ventral edges, where they form the strings, they are much larger, even in stringless varieties. The valves of the pod separate between two fan-shaped groups of bundle rays of the ventral string.

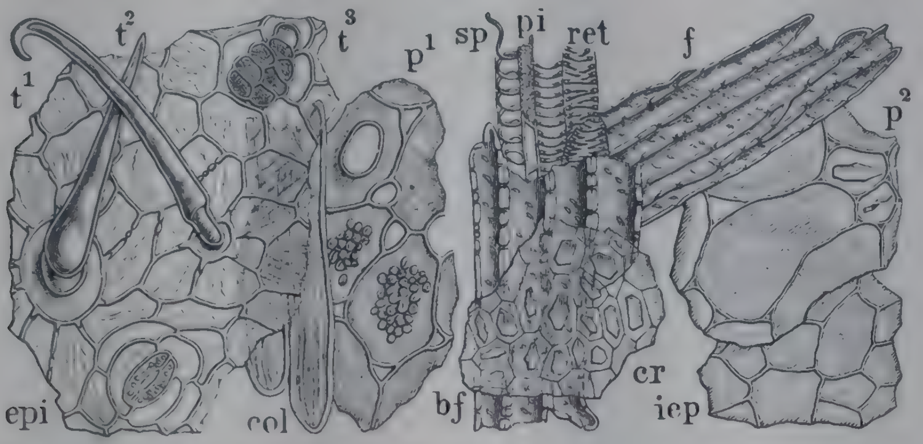

FIG. 100.—String Bean. Elements of immature pericarp in surface view. *epi* epicarp with stoma, t^1 hooked, t^2 straight, and t^3 capitate hairs; *col* collenchyma; p^1 outer mesocarp with starch grains; *cr* crystal layer, *bf* bast fibers, *sp* spiral, *pi* pitted, and *ret* reticulated vessels of "string"; *f* diagonal fibers; p^2 inner mesocarp with small crystal cells; *iep* endocarp. × 160. (K.B.W.)

The xylem shows spiral (*sp*), reticulated (*ret*), and pitted (*pi*) vessels, and the phloem large sieve tubes and delicate bast fibers (*bf*). Outside of the bundle groups on both edges, arranged end to end in longitudinal rows, are parenchyma cells, the walls of which finally become thickened and bright yellow in color, and outside of these are crystal cells (*cr*) with single crystals.

Spermoderm.—In the half-grown seed the cells of the outer *epiderm* (palisade cells) and *subepiderm* have reached nearly or quite their maximum height but only about half their maximum breadth. The pigmentation of colored beans is largely formed during a later stage. The crystals of the subepiderm are more slender than at full maturity.

Endosperm.—Evident at this stage.

Embryo.—At the half-ripe stage the cell walls of the *cotyledons* are beginning to show beads and the *starch aggregates* have reached about half their mature dimensions. The latter are of curious forms as shown in Fig. 101. Their compound nature is clearly shown at this stage, but later, as noted below, is obscured.

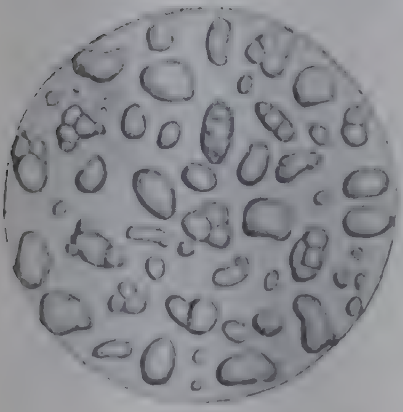

FIG. 101.—String Bean. Starch from half mature seed showing simple and compound grains. ×160. (K.B.W.)

MICROSCOPY OF SHELL BEAN.—At full maturity, whether moist or dry, the shell bean is the most pronounced type of common legume with prismatic (not spool-shaped) subepidermal cells, each containing an oxalate crystal; the tissues accordingly are shown in Figs. 102 and 103, not only in cross section but also in surface view.

Spermoderm.—The tissues are: (1) *palisade cells* (pal, pal^1, pal^2), forming the outer epiderm, reaching 60 μ in height and 10 μ in breadth, with a light line (l) just beneath the thin cuticle; (2) *subepiderm* (*sub*), the cells being in cross section quadrilateral, reaching 30 μ in height and breadth, in surface view polygonal, each with a perfectly formed or broken monoclinic crystal; (3) *spongy parenchyma* (p, p^1, p^2, p^3, p^4), with cells varying from without inward from thick to very thin-walled and from isodiametric to much branched; and (4) *inner epiderm* (*iep*) so collapsed as to be seen with difficulty in cross section, although its polygonal cells are visible in surface view after careful search.

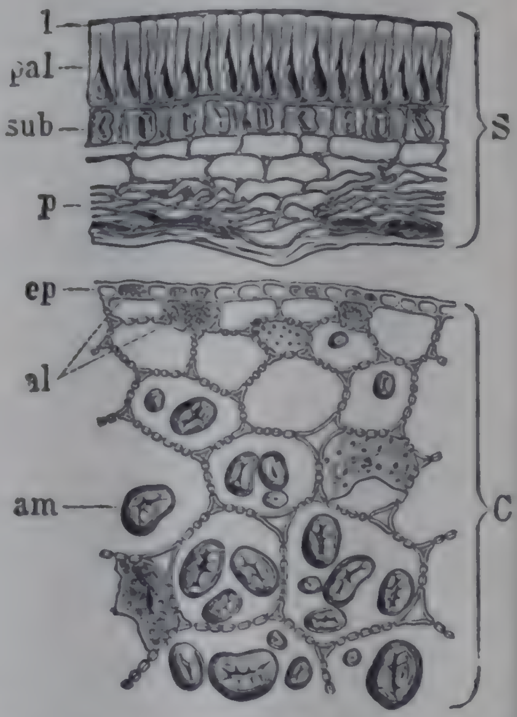

FIG. 102.—Common Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *l* light line, *sub* subepiderm containing crystals, *p* parenchyma. *C* cotyledon: *ep* outer epiderm, *al* aleurone grains and *am* starch grains of mesophyl. × 160. (A.L.W.)

The presence of *crystals* in the subepiderm is the noteworthy characteristic. In cross section, the cells are rectangular in outline, but the secondary walls, being irregularly thickened, often make the lumen spool-shaped. In surface view the secondary wall shows rifts indicative of broad ribs which escape notice in cross section.

About the sclerenchyma group in the hilum region the cells are thick-walled, often spool- or bone-shaped, and ribbed. They contain single crystals like those in the subepiderm.

Iere again the characters of the subepiderm are found in a tissue which s distinctly a continuation of the outer parenchyma. Even in colored seeds, the tissue is colorless.

Caruncle and Hilum Cushion.—Only a few, but well-developed, cells present.

Endosperm.—Seldom visible at maturity.

Embryo.—The cotyledons (*C*) are made up of isodiametric cells, those in the *epiderms* being small with non-porous walls and those in the *mesophyl* large with pores forming conspicuous beads.

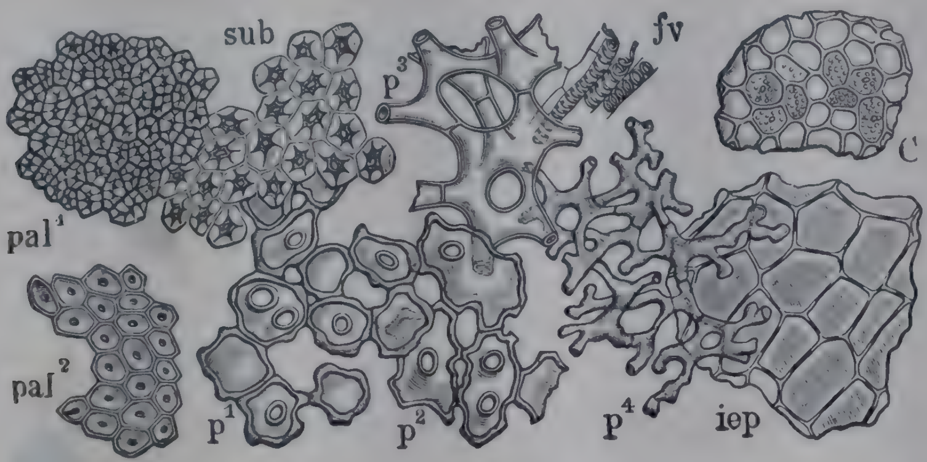

FIG. 103.—Common Bean. Elements of seed in surface view. Spermoderm: pal^1 palisade cells from above, pal^2 palisade cells from below, *sub* subepiderm (crystal cells), p^1, p^2, p^3, p^4 succeeding layers of parenchyma from without inward, *fv* fibro-vascular bundle, *iep* inner epiderm. *C* epiderm of cotyledon. × 160. (K.B.W.)

The *starch grains* are mostly ellipsoidal semiaggregates up to 60 μ long. On comparison with those of the pea, they have few excrescences corresponding to individual granules but most of them have a distinct axial rift and with polarized light show a dark V at each end connected by the rift.

Surrounding the starch grains is a matrix of protein matter which, as in the pea, becomes fixed on heating.

CHIEF STRUCTURAL CHARACTERS. **String Bean.**—Pod straight or curved, pointed, hairy, strings on dorsal and ventral edges.

Hairs of epicarp of three types, those with hooked ends highly characteristic; crystal layer not continuous (in edible-podded pea continuous); endocarp smooth (in edible-podded pea with papillæ and hairs); strings with conspicuous crystal cells.

Shell Bean.—Seed of various shapes and colors. Hilum in center of one edge; strophiole distinct; radicle not noticeable on surface.

Palisade cells up to 60 μ high and 10 μ broad; subepidermal cells up to 30 μ high and broad, each containing single crystal. Semiaggregate starch grains up to 60 μ long, more regularly oval than in pea without conspicuous excrescences, but often half-compound, with rifts. See also table p. 299.

CHEMICAL COMPOSITION OF STRING BEANS.—The following summary of 5 analyses of fresh string beans, from which an average of 7 per cent of refuse had been taken, is from Atwater and Bryant's compilation:[1]

Composition of String Beans (Atwater and Bryant)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	83.5	1.7	0.2	5.1	1.2	0.7
Max.	91.7	2.8	0.4	12.6	2.6	0.9
Aver.	**89.2**	**2.3**	**0.3**	**7.4**	**1.9***	**0.8**

* 2 analyses.

Minor Mineral Constituents.—Given with those of dried beans below.

CHEMICAL COMPOSITION OF AIR-DRY BEANS.—Below appear the range and average of 11 analyses of dried beans compiled by Atwater and Bryant,[2] also analyses of single samples by Peterson and Churchill[3] and Eichelberger.[4] Under Carbohydrates are given additional results on the single samples.

Composition of Dried Beans

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
A. and B.:						
Min.	9.6	19.9	1.4	57.2	3.2	2.7
Max.	15.5	26.6	3.1	63.5	7.2	4.4
Aver.	**12.6**	**22.5**	**1.8**	**59.6**	**4.4***	**3.5**
P. and C.	12.96	18.42	1.83	58.97	3.94	3.88
Eichelberger	10.08	22.69	2.36	57.82	3.62	3.43

* 4 analyses.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Loc. cit.

[3] J. Am. Chem. Soc. 1921, **43**, 1180.

[4] Ibid. 1922, **44**, 1407.

Proteins.—Ritthausen[1] isolated *phaseolin*, the principal protein of the common bean, from a brine extract and determined its ultimate composition.

Osborne[2] in like manner separated and analyzed phaseolin, also *phaselin*, an albumin. Proteose, alkali-soluble (but brine-insoluble), and alkali-insoluble proteins were also isolated, but in too small amount to warrant analysis. He estimated roughly the percentages of these proteins in the seed as being: phaseolin 15, phaselin 2, alkali-soluble protein 3.5, and alkali-insoluble protein 3, total 23.5 per cent.

Johns and Waterman[3] and Waterman, Johns, and Jones[4] report two globulins: (1) *phaseolin* or β-phaseolin, precipitated by ammonium sulphate at 0.57 to 0.80 saturation, and (2) *conphaseolin* or α-phaseolin, precipitated at 0.30 saturation, the latter being present in relatively small amount.

Ultimate Composition.—The results of the authors named follow:

	Phaseolin			Conphaseolin	Phaselin
	Ritthausen	Osborne	W. J. and J.	W. J. and J.	Osborne
	%	%	%	%	%
Carbon	52.55	52.58	52.56	53.81	51.60
Hydrogen	7.09	6.84	6.81	6.86	7.02
Nitrogen	16.18	16.47	16.13	15.73	14.65
Sulphur	0.43	0.56	0.33	1.36	0.49
Oxygen	23.75	23.55	24.17	22.24	26.24
	100.00	100.00	100.00	100.00	100.00

Amino Acids of Phaseolin.—Osborne and Clapp,[5] employing Fischer's method, determined the percentages of amino acids resulting from hydrolysis. Their results on the monoamino acids, together with those of Finks and Johns[6] on cystine and hexone bases obtained in the main by Van Slyke's method, appear in the table which follows:

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[1] J. prakt. Chem. 1884, **29**, 448.

[2] J. Am. Chem. Soc. 1894, **16**, 633, 703, 757.

[3] J. Biol. Chem. 1921, **46**, xliv.

[4] Ibid. 1923, **55**, 93.

[5] Am. J. Physiol. 1907, **18**, 295.

[6] J. Biol. Chem. 1920, **41**, 375.

PRODUCTS OF HYDROLYSIS OF PHASEOLIN

	%
Glycocoll	0.55
Alanine	1.80
Valine	1.04
Leucine	9.65
Serine	0.38
Cystine	0.84
Aspartic acid	5.24
Glutamic acid	14.54
Tyrosine	2.14
Phenylalanine	3.25
Proline	2.77
Tryptophane	+
Arginine	6.11
Lysine	7.88
Histidine	3.32
Ammonia	2.06
	61.57

Jones, Gersdorff, and Moeller,[1] in the globulins of the red kidney bean and the navy bean, obtained the following figures for cystine and tryptophane:

	Red Kidney Bean	Navy Bean		
	Total globulin	Total globulin	Conphaseolin (α-globulin)	Phaseolin (β-globulin)
	%	%	%	%
Cystine	1.00	1.59	1.53	0.58
Tryptophane	1.34	1.52	2.79	0.94

Nitrogen Distribution in Bean Proteins.—The results of Finks and Johns and of Waterman, Johns, and Jones appear on the next page.

Fat.—Grimme[2] determined the values of the fat, forming 1.32 per cent of the kernel, with the following results: specific gravity at 15° C. 0.9179, refractive index at 25° C. 1.4861, solidifying point −4° C., saponification number 189.2, iodine number 135.7, fatty acids 87.51 per cent, titer (solidifying point of the fatty acids) 19° C., and unsaponifiable matter 5.85 per cent.

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[1] J. Biol. Chem. 1924, **62**, 183.

[2] Pharm. Zentralh. 1911, **52**, 1141.

	Phaseolin		Conphaseolin
	F. and J.	W. J. and J.	W. J. and J.
	%	%	%
Humin N adsorbed by lime	1.72	0.71	2.82
Humin N in amyl alcohol extract	0.31		0.19
Cystine N	0.61	0.83	0.88
Arginine N	12.31	12.57	14.15
Lysine N	9.49	11.10	13.14
Histidine N	5.62	3.93	1.47
Amino N of filtrate	54.94	59.81	57.53
Non-amino N of filtrate	3.90	0.18	2.58
Amide N	10.89	10.95	7.39
	99.79	100.08	100.15

Acids.—Arbenz[1] found 0.045 and Viehoever, Kunke, and Mastin[2] 0.4 per cent of *oxalic acid.*

Carbohydrates.—Peterson and Churchill,[3] noting the dearth of literature on the carbohydrates of legumes other than investigations made prior to 1900 and the entire lack of full analyses of the common bean, determined, in addition to the usual groups (see above), the individual carbohydrates.

Eichelberger[4] reports an analysis agreeing closely, on the whole, with that of the foregoing authors.

The percentages of *total sugars, dextrins,* and *starch* given below were in both analyses obtained by practically the same method, but the percentage of *pentosans,* as reported by Peterson and Churchill, is the

CARBOHYDRATES OF COMMON (NAVY) BEAN

	Sugars	Dextrins	Starch	Pentosans	Galactans	Hemicellulose	Cellulose	Acids, waxes, etc.*
	%	%	%	%	%	%	%	%
P. and C.	1.59	3.71	35.20	8.37	1.33	0.83	3.11	8.77
Eichelberger	2.61	3.23	35.22	8.08	......	....	......	7.86

* By difference.

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[1] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[2] Science 1917, **46**, 546.

[3] Loc. cit.

[4] Loc. cit.

sum of determinations made in fractions by different solvents, whereas that by Eichelberger is of a single direct determination. Eichelberger also reported 8.90 per cent of insoluble *hemicellulose*—the carbohydrate matter including pentosans obtained by acid hydrolysis of the water-insoluble material less that found after disastase hydrolysis.

Lupeose, stachyose, and paragalactoaraban, which Schulze and his co-workers found in the lupine and pea groups, do not appear in the above analyses. Tanret[1] isolated 2.1 per cent of *stachyose* and 3.9 per cent of *sucrose* in the common bean.

The hulls of the common bean were estimated by Schulze and Pfenninger[2] to contain according to the degree of ripeness 19.35, 15.65, and 48.65 per cent of *hemicellulose*, which yielded galactose and arabinose, but only a small amount of fructose, on hydrolysis.

Tractta-Mosca,[3] in the dialyzed water extract of kidney beans, peas, and lentils which had been heated at 100° C. to destroy enzymes, identified *galactose* by the phenylosazone method.

Enzymes.—As shown by Thunberg,[4] the seeds are very rich in oxidizing enzymes known as *deshydrogenases*. Neutralized formic, malic, succinic, α-ketoglutaric, and glutamic acids, as well as some other substances, promote the oxidizing action.

Amylase.—Sjöberg[5] has made an extensive study of the amylase of various parts of the bean plant. Its greatest activity in phosphate-buffered mixtures at 40° C. is *p*H 5.0. The optimum *p*H for sugar formation is 5.0 to 5.5, and for starch disappearance 4.0 to 6.0.

Mineral Constituents.—The following average of 13 analyses is from Wolff:[6]

COMPOSITION OF BEAN ASH (WOLFF)

Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
3.22	44.01	1.49	6.38	7.62	0.32	35.52	4.05	0.57	0.86

Minor Mineral Constituents. *Iron.*—Dried navy beans 67, fresh string beans 16 mg. per kilo (Sherman).[7] Dried " white beans " 73 mg. per kilo (Bunge).[8] Beans:

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[1] Compt. rend. 1912, **155**, 1526.

[2] Z. physiol. Chem. 1910, **68**, 93.

[3] Ann. ist. super. agr. Portici 1929, [3], **3**, 164.

[4] Arch. intern. physiol. 1921, **18**, 601.

[5] Biochem. Z. 1922, **133**, 218, 294.

[6] Aschenanalysen.

[7] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[8] Z. physiol. Chem. 1884/5, **9**, 49.

Tennessee Green Pod 100, Kentucky Wonder 110 and 128 mg. per kilo, dry basis (McHargue).[1] String beans 9.3 mg. per kilo, fresh basis; dried kidney beans 69.2, dried navy beans 95.2 mg. per kilo, air-dry basis (Peterson and Elvehjem).[2] String beans, 2 samples, 6.3, 10.5 mg. per kilo, fresh basis (Toscani and Reznikoff).[3] String beans (green seeds and pods), 15 samples, 140 to 370, aver. **201** mg. per kilo, dry basis (Remington and Shiver).[4] The fresh material examined by the last-named authors contained 5.7 to 10.1, aver. **8.5** per cent of dry matter, hence the average amount of iron in the original beans was 17.1 mg. per kilo.

Blunt and Otis[5] found that the loss of iron on boiling navy beans was 39 and string beans 43 per cent of the whole.

Aluminum.—String beans 6.3 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[6] String beans 8, shelled beans 1.3 mg. per kilo, dry basis (Bertrand and Lévy).[7]

Manganese.—Beans: Tennessee Green Pod 17, Kentucky Wonder 16 and 18 mg. per kilo, dry basis (McHargue).[1] Kidney beans 14.5, French beans 13.5 mg. per kilo (Quartaroli).[8] String beans (green seeds and pods), 13 samples, 16.2 to 55.9, aver. **35.2** mg. per kilo, dry basis, equivalent to 3 mg. in the fresh material (Remington and Shiver).[9]

Copper.—French beans, 1.8 mg. per kilo, fresh basis, 16.3 mg. per kilo, dry basis; kidney beans: seeds 10, pods 7.2 mg. per kilo, air-dry basis (Guérithault).[10] Kidney beans: green, seed 11, pod 9; ripe, seed 11, pod 4.5 mg. per kilo, dry basis (Maquenne and Demoussy).[11] Seeds 6.2 mg. per kilo, dry basis (Hirano and Mikumo).[12] String beans (green pods and seeds), 14 samples, 5.8 to 15.3, aver. **9.6** mg. per kilo, dry basis, equivalent to 0.8 mg. in the fresh material (Remington and Shiver).[9] French beans 16.66, kidney beans 14.80 mg. per kilo (Quartaroli).[13] Navy beans 10.45 mg. per kilo (Satterfield and Jones).[14] String beans 1.0 mg. per kilo, fresh basis; dried navy beans 6.9, dried kidney beans 6.5 mg. per kilo, air-dry basis (Lindow, Elvehjem, and Peterson).[15]

Zinc.—Kidney beans: seed 52.5, string beans, whole pod 0.8 mg. per kilo, fresh basis (Bertrand and Benzon).[16]

Arsenic.—White beans 0.1 mg. per kilo (Jadin and Astruc).[17]

Iodine.—Seeds none (Winterstein).[18]

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[1] J. Agr. Res. 1923, **23**, 395.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] J. Nutrition 1934, **7**, 79.

[4] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[5] J. Home Econ. 1917, **9**, 213.

[6] Am. J. Physiol. 1929, **90**, 72.

[7] Bul. soc. hyg. aliment. 1931, **19**, 359.

[8] Ann. chim. appl. 1928, **18**, 47.

[9] Loc. cit.

[10] Compt. rend. 1920, **171**, 196.

[11] Ibid. 1920, **170**, 87.

[12] J. Pharm. Soc. Japan 1925, **525**, 992.

[13] Loc. cit.

[14] J. Elisha Mitchell Sci. Soc. 1932, **48**, 16.

[15] J. Biol. Chem. 1929, **82**, 465.

[16] Bul. soc. hyg. aliment. 1928, **16**, 457.

[17] Compt. rend. 1912, **155**, 291.

[18] Z. physiol. Chem. 1918, **104**, 54.

TEPARY

Phaseolus acutifolius var. *latifolius* Freeman

This small bean is a native of the deserts of southwestern United States where it has been cultivated by the Indians since prehistoric times. Freeman[1] describes it in detail and states that the dry shell beans may become a staple crop of hot arid regions.

MACROSCOPIC STRUCTURE.—The spreading or twining *stem* is more slender than that of the common bean and the leaves and pods are smaller; the *flowers* are white or blue. The *pod* is flat, about 8 cm. long and 1 cm. wide. The seeds, 2 to 7 in a pod, are commonly white, less often yellow, brown, or black, 4 to 8 mm. long, often as broad as long, rounded or somewhat flattened.

MICROSCOPIC STRUCTURE.—As regards the histology, the tepary may be described as being the common bean in miniature.

Spermoderm.—The tissues are: (1) *palisade cells*, 45 μ high and 15μ broad, with flattened outer ends, (2) *subepiderm* of prismatic cells about 27 μ high and half as broad, with spool-shaped lumens, each containing a single (rarely two) monoclinic crystal up to 15 μ long, and (3) characterless *parenchyma*.

Endosperm.—Cells not evident.

Embryo.—The porous *mesophyl cells* of the two large cotyledons contain starch grains of the common bean type, up to 35 μ in length.

CHIEF STRUCTURAL CHARACTERS.—Seeds, commonly white, rounded or somewhat flattened, hilum small.

Palisade cells, up to 45 μ high, with flattened outer ends; subepidermal cells prismatic, up to 27 μ high, with spool-shaped lumens, each containing one to two crystals. Starch of cotyledons of common bean type, up to 35 μ long. See also table p. 299.

CHEMICAL COMPOSITION.—Analyses reported by Freeman[2] and by Jaffa and Albro[3] follow:

COMPOSITION OF TEPARIES

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Freeman:						
Teparies........	9.50	22.18	1.43	59.32	3.36	4.21
Jaffa and Albro:						
White teparies..	10.28	20.30	1.49	60.14	3.79	4.00
Pods...........	8.00	4.14	0.55	43.51	36.97	6.82

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[1] Arizona Agr. Exp. Sta. 1912, Bul. **68**.

[2] Ibid. 1912, Bul. **68**, 573.

[3] California Agr. Exp. Sta. 1918, Bul. **294**, 341.

SCARLET RUNNER

Phaseolus multiflorus Willd.

Fr. Haricot d'Espagne. Ger. Feuerbohne.

A native of Mexico and other parts of tropical America where it is prized for its nutritious seeds, the scarlet runner is widely cultivated both as an ornamental and food plant.

MACROSCOPIC STRUCTURE.—As indicated by the name, the *flowers* are a vivid scarlet. They are of considerable size and are borne in racemes. The flattened, pointed *pod* reaches 15 cm. in length. It contains several much-flattened, kidney-shaped *seeds* (Fig. 104) often over 2.5 cm. long and half as broad, glossy black with pink blotches on and about the edges. The hilum is 5 to 6 mm. long, covered with a white spongy cushion with a very narrow caruncle or rim. Raphe, strophiole, and micropyle are evident to the naked eye.

MICROSCOPIC STRUCTURE (Fig. 105).—A study of the histology, as first carried out by Harz,[1] shows a relationship with the common bean in harmony with its classification in the same genus but as a separate species.

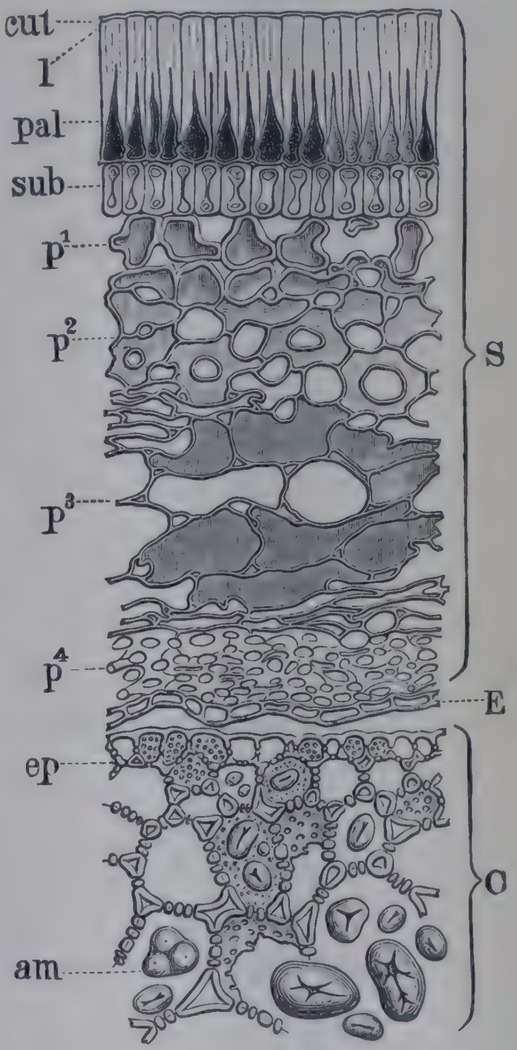

FIG. 105.—Scarlet Runner. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm with crystals, p^1, p^2, p^3 (with pigment), and p^4 spongy parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, *am* starch grains of mesophyl. × 160. (K.B.W.)

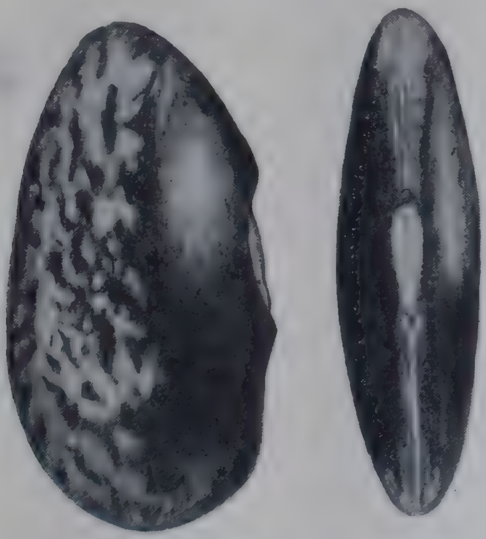

FIG. 104.—Scarlet Runner. Seed. × 2. (A.L.W.)

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[1] Samenkunde, Berlin, 1885, p. 729.

Spermoderm (*S*).—Cross sections, as well as surface mounts, bring out three layers, the third showing differentiation into several forms of tissues although not sharply defined: (1) *palisade cells* (*pal*), up to 85 μ high and 15 μ broad, each in the outer portion with obliterated or narrow lumen and in the inner end with a bulbous enlargement, containing in certain parts a deep blue substance; (2) *subepiderm* (*sub*) of prismatic cells, up to 30 μ high and 40 μ broad, each with spool-shaped lumen containing in the outer part, less often in the inner part, a small oxalate crystal; and (3) *spongy parenchyma* varying much as in common bean from irregular but nearly isodiametric, thick-walled cells (p^1) into branching cells with large round intercellular spaces (p^2), then into large cells with small triangular spaces, containing a pink or brown substance (p^3), and finally into typical spongy parenchyma with small cells and very thin walls (p^4).

The *subepiderm* is intermediate between the bean type and the pea type; in their prismatic outer contour the cells are like the former, in their marked spool-shaped inner contour the latter.

In the dry seed, the *parenchyma tissues* are more or less compressed, and it is only by careful manipulation that they show their characters in cross section. Beneath the hilum the cells are thick-walled, irregular in outline, forming a very spongy tissue with dark contents. Conspicuous crystals, such as occur in the common bean, are lacking.

The dark *color* of the seed is due to the contents of the palisade cells, the pink blotches to the pigment in the spongy parenchyma showing through empty palisade cells.

Caruncle.—The cells form a palisade layer of moderate height.

Hilum Cushion.—The tissue is *spongy parenchyma* without evident contents.

Endosperm (*E*).—A single layer of *aleurone cells* is evident at full maturity in carefully cut and cleared mounts. In the common bean the corresponding layer disappears on ripening.

Embryo.—The cotyledons (*C*) as in the common bean lack palisade cells and have porous walls. Ellipsoidal, reniform, triangular, and irregular aggregate and semiaggregate *starch grains* (*am*), up to 50 μ, often with rifts, are the conspicuous contents.

Chief Structural Characters.—Seeds flattened, up to more than 2.5 cm.; black with pink blotches on and near edges; hilum covered with white cushion.

Palisade cells up to 85 μ high and 15 μ broad; prismatic subepidermal cells up to 30 μ high and 40 μ broad, each with spool-shaped lumen, containing 1 to 2 minute crystals; spongy parenchyma of various types. Caruncle of palisade cells. Spongy parenchyma of hilum cushion empty. Endosperm of single layer of aleurone cells. Cotyledon without palisade cells, walls porous; starch grains up to 50 μ. See also table p. 299.

DUTCH CASE-KNIFE BEAN

Phaseolus multiflorus Willd.

Although this legume is considered a white variety of the scarlet runner, the seed sold by American seedsmen differs so markedly in certain histological characters as to suggest other relationship.

MACROSCOPIC STRUCTURE.—The seeds resemble Sieva beans, varying up to 18 mm. in length and about half that in breadth.

MICROSCOPIC STRUCTURE.—The *palisade cells* vary up to 50 μ high and 16 μ broad, and the *subepidermal cells* up to 27 high and 25 broad. The latter are prismatic and thin-walled as in the common bean, without spool-shaped lumens. A single crystal even larger than in the common bean occurs in each cell.

CHIEF STRUCTURAL CHARACTERS.—Seed resembles the Sieva bean.

Palisade cells up to 50 μ high; suberpidermal cells with crystals. See also table p. 299.

LIMA BEAN

Phaseolus lunatus L. var. *macrocarpus* Benth.

Fr. Haricot de Lima. Ger. Mondbohne.

Although the true or large-seeded Lima bean, a native of South America, is a perennial in the tropics, it is grown as an annual in the temperate zone. It should not be confused with the small Lima or Sieva bean (*P. lunatus* L.), which is regarded as the type of the species, nor with other large or flat-seeded legumes sometimes erroneously known as Limas, such as the scarlet runner, the case-knife bean, or the jack bean.

The green shelled beans, as well as succotash (Lima beans and green corn), are canned in large quantities. Dry mature Lima beans, grown especially in California, are sold for boiling and baking.

MACROSCOPIC STRUCTURE.—Two types are in cultivation, the common or flat and the potato. In the latter the *pod* is shorter, thicker, and less pointed. Both have tall and dwarf varieties. The white *flowers* are in racemes. *Seeds* of the common Lima bean (Fig. 106) are much flattened, often over 2.5 cm. long and about two-thirds as broad. Commonly the seeds are white, but there are varieties with orange, red, black, or spotted seeds. The hilum reaches 6 mm. in length; characteristic wrinkles or lines radiate from it. Strophiole and micropyle are evident, also caruncle and funicular tissues forming a hilum cushion.

MICROSCOPIC STRUCTURE (Fig. 107).—Credit is due Harz[1] as the pioneer in the study of this as well as many other legumes.

Spermoderm (*S*).—Cross sections and surface mounts show: (1) *palisade cells* (*pal*) up to 85 μ high and 20 μ broad, each with flat outer end, narrow light line (*l*), and thin cuticle (*cut*); (2) *subepiderm* (*sub*) of narrow, spool- or bone-shaped cells reaching the remarkable height of 65 μ, 30 μ broad; (3) *spongy parenchyma*, with somewhat thickened walls and large intercellular spaces in the outer portion (p^1), with large cells and smaller intercellular spaces in the middle portion (p^2), and with small, very thin-walled cells in the inner portion (p^3); and (4) small-celled *inner epiderm* (*iep*).

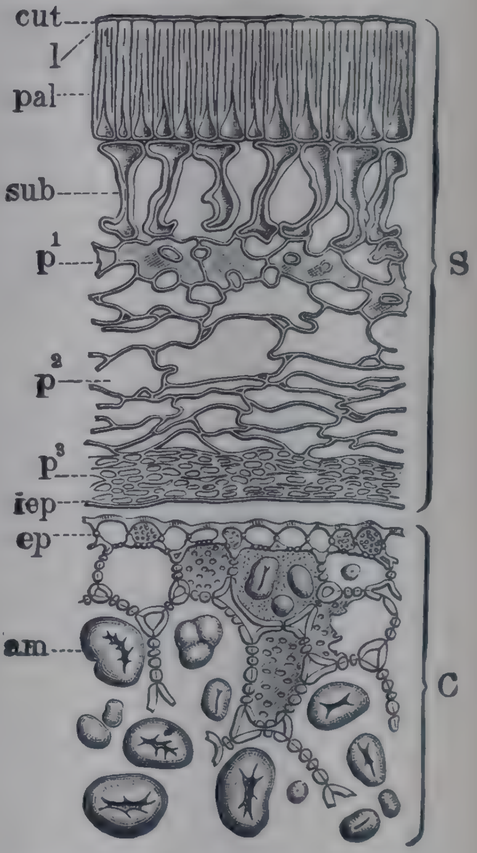

FIG. 107.—Lima Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, p^1, p^2, p^3 spongy parenchyma, *iep* inner epiderm. *C* cotyledon: *ep* outer epiderm, *am* starch grains of mesophyl. × 160. (K.B.W.)

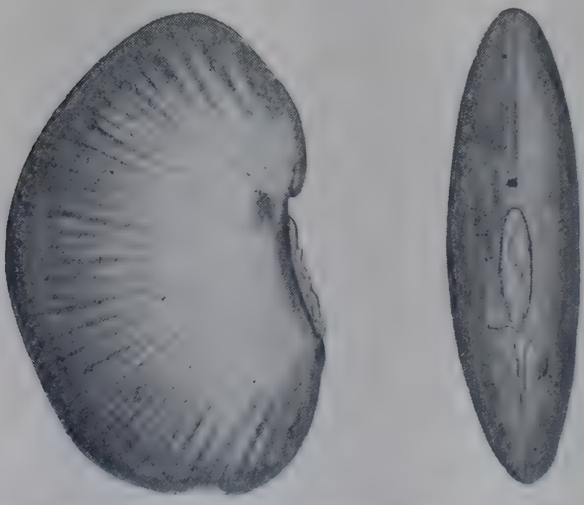

FIG. 106.—Lima Bean. Seed. × 2. (A.L.W.)

Beneath the hilum the tissue is very spongy, colorless, with thick walls. The individual cells are irregular in outline.

Caruncle and Hilum Cushion.—Well-developed palisade cells form the caruncle, and colorless, rounded cells in loose contact, the cushion.

Endosperm.—Not evident.

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[1] Samenkunde, Berlin, 1885, p. 732.

Embryo.—In the structure of the cotyledons (*C*), the Lima bean resembles the common bean. As in the latter, the walls are strongly porous, and the aggregate and semiaggregate *starch grains* (*am*), up to 65 μ, are for the most part irregularly ellipsoidal or kidney-shaped with clefts.

CHIEF STRUCTURAL CHARACTERS.—Seeds large, flattened, with wrinkles radiating from the hilum; caruncle and hilum cushion present.

Epidermal palisade cells up to 85 μ high and 20 μ broad; subepidermal cells spool- or bone-shaped, up to 65 μ high and 30 μ broad. Caruncle of palisade cells and hilum of rounded cells in loose contact. Starch grains up to 65 μ, commonly ellipsoidal or reniform with clefts, also trefoil- and various-shaped aggregates. See also table p. 299.

CHEMICAL COMPOSITION.—The following table contains a summary of analyses of the common white Lima bean, both fresh and dried, grown in the United States, as compiled by Atwater and Bryant,[1] and of the fresh bean by Agcaoili,[2] also an analysis of the Rangoon bean by Beythien and Hempel[3] and of *hontei-tan* by Okumura,[4] both of which are classified under *P. lunatus* (see Sieva Bean):

COMPOSITION OF LIMA AND RELATED BEANS

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Fresh Lima beans:							
A. and B.	1	68.5	7.1	0.7	20.3	1.7	1.7
Agcaoili.	1	65.50	7.30	1.26	23.37	0.77	1.84
Dried Lima beans:							
A. and B.	4						
Min.	. .	8.3	12.8	0.6	61.6*	. . . .	3.6
Max.	. .	12.2	24.5	1.9	70.1*	. . . .	4.7
Aver.	. .	**10.4**	**18.1**	**1.5**	**65.9***	. . . .	**4.1**
Rangoon beans:							
B. and H.	1	11.74	17.24	1.43	58.90	6.63	4.06
Hontei-tan:							
Okumura.	1	60.10	10.44	0.51	24.23	2.46	2.26

* Includes fiber.

Proteins.—Preparations from seeds of a pole and a bush variety, made by Jones, Gersdorff, Johns, and Finks,[5] were found to be identical.

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[1] U. S. Dept. Agr. Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] Pharm. Zentralh. 1920, **61**, 27.

[4] J. Tokyo Chem. Soc. 1920, **41**, 556.

[5] J. Biol. Chem. 1922, **53**, 231.

The bean contained 3.38 per cent of nitrogen in the form of proteins of which 72.32 per cent was soluble in 3 per cent salt solution at ordinary temperature. *α-Globulin* (2.74 per cent) separated on adding ammonium sulphate to 0.25 saturation and *β-globulin* (7.47 per cent) on increasing the amount to between 0.45 and 0.75 saturation. An *albumin* (8.25 per cent) was obtained from a water extract from which the globulins had been removed by dialysis and treatment with carbon dioxide.

The *Ultimate Composition* of the proteins, as determined by the authors named above, follows:

	α-Globulin	β-Globulin	Albumin
	%	%	%
Carbon	53.65	52.72	54.17
Hydrogen	6.65	6.77	6.63
Nitrogen	15.55	14.81	14.22
Sulphur	1.27	0.35	1.15
Oxygen	22.88	25.35	23.83
	100.00	100.00	100.00

Amino Acids of Lima Bean Proteins.—Jones, Gersdorff, and Moeller[1] obtained the following figures on cystine and tryptophane respectively: α-globulin 1.56 and 1.92, β-globulin 0.82 and 2.16, total globulin 0.78 and 1.77, and albumin 1.11 and 1.37 per cent.

Nitrogen Distribution.—Determinations by Jones, Gersdorff, Johns, and Finks[2] yielded the following results:

	α-Globulin	β-Globulin	Albumin
	%	%	%
Humin N adsorbed by lime	2.01	1.57	1.86
Humin N adsorbed by amyl alcohol-ether	0.21	0.07	0.19
Cystine N	1.20	0.67	0.88
Tryptophane N	+	+	+
Arginine N	11.72	11.02	12.97
Lysine N	9.67	11.04	8.04
Histidine N	6.46	4.80	4.88
Amino N of filtrate	55.69	59.75	62.66
Non-amino N of filtrate	2.89	1.55	0.61
Amide N	10.31	10.19	9.78

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[1] J. Biol. Chem. 1924, **62**, 183.

[2] Loc. cit.

Minor Mineral Constituents. *Iron.*—Pole Lima 80, bush Lima 100 mg. per kilo, dry basis (McHargue).[1] Lima 116.6 mg. per kilo, air-dry basis (Peterson and Elvehjem).[2] Fresh beans, 2 samples, 20.9, 22.0 mg. per kilo, fresh basis (Toscani and Reznikoff).[3]

Manganese.—Pole Lima 18, bush Lima 19 mg. per kilo, dry basis (McHargue).[1]

Copper.—Lima 8.6 mg. per kilo (Satterfield and Jones).[4] Lima 8.6 mg. per kilo, air-dry basis (Lindow, Elvehjem, and Peterson).[5]

SIEVA BEAN

Phaseolus lunatus L.

Fr. Haricot de Java. Ger. Sievabohne.

The Sieva or civet bean, often confused with the true Lima, is a native of tropical America. The typical form is a low climber, but there are dwarf varieties such as Henderson Dwarf Lima. Under the name of Java, Rangoon, and Burman beans, both colored and white seeds, stated to be of *P. lunatus*, are shipped to Europe from the East Indies. It is these beans from the Far East which have been found to contain considerable amounts of cyanogenetic glucosides.

MACROSCOPIC STRUCTURE.—The *plants* of both tall and dwarf varieties of Sieva beans are distinguished from the Limas by the much more delicate habit of growth. The small, curved, and pointed *pod* contains, as in the Lima, flattened *seeds*, varying in color from white to brown, or mottled, but they are much smaller (up to 1.75 cm. in length). Only the white-seeded varieties are commonly grown in the United States.

MICROSCOPIC STRUCTURE.—Beans of the tall and dwarf varieties found on the American market are indistinguishable from each other and both closely resemble the true Limas except that the *palisade cells* seldom if ever are as high (usually less than 60 μ).

CHEMICAL COMPOSITION.—Proximate analyses of the Rangoon bean and *hontei-tan* are given under Lima Bean. No analysis of the white Sieva bean as grown in the United States is available.

Nitrogenous Bases.—In air-dry *hontei-tan*, Okumura[6] found *adenine* as chloride 0.004, *arginine* as nitrate 0.009, *histidine* as chloride 0.004, *choline* as double platinum salt 0.063, and *trigonellin* as chloride 0.063 per cent.

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[1] J. Agr. Res. 1923, **23**, 395.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] J. Nutrition 1934, **7**, 79.

[4] J. Elisha Mitchell Sci. Soc. 1932, **48**, 16.

[5] J. Biol. Chem. 1929, **82**, 465.

[6] J. Tokyo Chem. Soc. 1920, **41**, 556.

Cyanogenetic Glucosides.—No evidence is at hand that the Lima bean or the white Sieva bean, as grown in American gardens, contains an appreciable amount of cyanogenetic glucosides, but much has been written on the glucoside *phaseolunatin* present in seeds of wild varieties of *P. lunatus*, notably Java, Burman, and Rangoon beans, which through enzyme action splits up with the formation of hydrocyanic acid. Gilkinet,[1] in discussing claims of Dunstan and Henry[2] and Jorissen[3] for the discovery of *linamarin*, the cyanogenetic glucoside of the flax plant, states that linamarin and phaseolunatin are probably identical.

Kohn-Abrest[4] determined the hydrocyanic acid liberated by water and subsequently by hydrochloric acid in 8 samples of variously colored Java beans, 6 samples of Burman beans, and 2 samples of colored Burman beans, with results ranging respectively as follows: water-soluble 37 to 127, 5 to 12, and 7 to 9; acid-soluble 13 to 37, 3 to 9, and 4; total 53 to 164, 9 to 20, and 11 to 13 mg. per kilo. Arragon[5] found only 3.68 to 4.82 mg. per 100 grams in Indians amples; Hendrick[6] found as much as 216 mg. per 100 grams in Java beans but smaller amounts in Burman or Rangoon beans.

It is stated by Dunlop[7] and some other writers that it is the dark-colored seeds of Java beans which yield considerable amounts of hydrocyanic acid; Simpson,[8] however, found that the only variety examined by him which yielded over 40 mg. per 100 grams was *Rangoon blanca*, the remainder yielding only 3 to 8 mg. or none, and Kohn-Abrest, as noted above, found small amounts in colored Burman beans.

Serrano[9] reports in dried wild, semi-wild, and cultivated beans 60 to 240, 49 to 55, and 30 mg. and in green wild and cultivated beans 30 and 11 mg. per 100 grams respectively. In *Phaseolus mungo, Psophocarpus tetragonolobus*, and *Vigna sinensis* he was unable to find any hydrocyanic acid.

Guignard[10] found that the glucoside disappears on sprouting, except in etiolated parts. Sudendorf and Gahrtz,[11] on the other hand, found that the amounts of hydrocyanic acid increased during fermentation.

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[1] Bul. soc. belg. chim. 1907, 799.

[2] Ibid. 1907, 790.

[3] Ibid. 1907, 793.

[4] Mon. sci. 1906, **64**, 797.

[5] Z. Unters. Nahr.-Genussm. 1906, **12**, 530.

[6] Trans. Highland Agr. Soc. Scotland 1907, **19**, 139.

[7] W. Indian Bul. 1915, **15**, 29.

[8] Ann. acad. cien. med., fis., nat., Habana 1918, **55**, 250.

[9] Philippine Agr. 1923, **11**, 163.

[10] Compt. rend. 1908, **147**, 1023.

[11] Z. Unters. Nahr.-Genussm. 1920, **39**, 350.

Government limits for hydrocyanic acid vary with the time and country. Dunbar[1] refers to the German limit of 35 mg. and Barilli[2] and Guignard[3] to the French limit of 20 mg. per 100 grams.

Arragon,[4] Hendrick,[5] Whirtle and Rheinberger,[6] Berg,[7] and others state that by soaking in water, boiling, and rejecting the liquid the beans are rendered harmless. Serrano,[8] however, found that although 95 per cent of the hydrocyanic acid was removed by boiling 2 hours, the part remaining imparted a bitter taste. Complete removal was effected by adding acetic acid to the liquid in which the beans were boiled, the acid being neutralized finally with lime water. Cohn[9] very properly calls attention to the losses resulting from the rejection of the liquid in which the beans have been soaked and boiled, amounting in his experience to 15 per cent of the nitrogenous substances and carbohydrates and 50 per cent of the ash.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[10] found 0.87 per cent, dry basis.

Enzymes.—See Cyanogenetic Glucosides above.

Mineral Constituents.—An analyses of the ash of *hontei-tan* by Okumura[11] gave:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%
53.80	2.26	2.51	6.40	0.10	0.10	14.71	2.14	0.73	0.54

MOTH BEAN

Phaseolus aconitifolius Jacq.

The moth bean is cultivated in its native habitat, India, both for human food and forage.

MACROSCOPIC STRUCTURE.—The *plant* is trailing, 1 to 2 feet long, the *leaflets* are lobed, the *flowers* small, yellow, in heads. The *pod* is about 5 cm. long, with cylindrical *seeds* up to 4 mm. long and half as broad, dirty gray-brown in color.

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[1] Gesundh. Ing. 1920, **43**, 97.

[2] J. pharm. chim. 1908, [6], **29**, 422.

[3] Ann. fals. 1916, **9**, 301.

[4] Loc. cit.

[5] Loc. cit.

[6] Z. Unters. Nahr.-Genussm. 1920, **39**, 346.

[7] Chem. Ztg. 1920, **44**, 526.

[8] Loc. cit.

[9] Chem. Ztg. 1921, **45**, 86, 101.

[10] Philippine Agr. 1932, **21**, 53.

[11] Loc. cit.

MICROSCOPIC STRUCTURE. Spermoderm.—The tissues are: (1) *palisade cells,* up to 40 μ high and 15 μ broad, with flat outer ends, (2) *subepiderm* of spool-shaped cells about 10 μ high and 20 μ broad, and (3) *parenchyma.*

Endosperm.—No cells evident.

Embryo.—Mesophyl cells of *cotyledon,* porous-walled, containing starch grains up to 27 μ long, mostly ellipsoidal, some being semiaggregates.

CHIEF STRUCTURAL CHARACTERS.—Seed up to 4 mm. long, dirty gray-brown in color.

Palisade cells up to 40 μ high, subepiderm spool-shaped, starch grains up to 27 μ long, ellipsoidal, occasionally semiaggregates. See also table p. 299.

CHEMICAL COMPOSITION.—The following analysis is given by Church:[1]

COMPOSITION OF MOTH BEAN

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
11.2	23.8	0.6	56.6	4.2	3.6

RICE BEAN

Phaseolus calcaratus Roxb.

This legume, resembling the adzuki in its habits, is a native of Asia where it is now extensively cultivated.

MACROSCOPIC STRUCTURE.—The *stem* is erect; the *leaves* are entire; the *flowers* are yellow. The *seed* is small, up to 9 mm. long and half as broad, varying in color from bright red to colorless, with large white hilum.

MICROSCOPIC STRUCTURE. Spermoderm.—The tissues are: (1) *palisade cells,* up to 55 μ high and 15 μ broad, with flattened outer ends, a light line, and lumens broadening from base outward, (2) *subepiderm* up to 10 μ high and 30 μ broad, of delicate spool-shaped cells, without evident ribs, and (3) characterless *parenchyma.* The color is largely in the palisade cells.

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[1] Food Grains of India, London, 1886, p. 151.

Hilum Cushion.—This consists of a mass of thin-walled cells filled with small rounded *starch grains.*

Endosperm.—Cells not evident.

Embryo.—The indistinctly porous mesophyl cells of the *cotyledon* contain large aggregate and semiaggregate starch grains up to 70 μ, varying from ellipsoidal, in the common garden bean type, to rounded, in the adzuki type. Numerous aleurone grains accompany the starch.

CHIEF STRUCTURAL CHARACTERS.—Seed small, red to colorless, with large white hilum.

Palisade cells up to 55 μ, subepiderm spool-shaped, starch grains up to 70 μ, ellipsoidal or round. See also table p. 299.

CHEMICAL COMPOSITION.—The following analysis is by Church:[1]

COMPOSITION OF RICE BEAN

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
10.5	21.7	0.6	58.1	5.2	3.9

MUNG BEAN

Phaseolus aureus Roxb.

The name mung often has been applied to *P. Mungo*, but the latter is now commonly known as the urd.

Bean Sprouts, a stable article of diet among the Chinese and a common ingredient of chop suey, are prepared by thoroughly soaking the beans and germinating under a damp cloth for several days. Canned sprouts are now obtainable throughout the United States.

Blasdale[2] states that the Chinese in the vicinity of San Francisco prepare sprouts from green and red varieties of *P. Mungo*, as well as from *Dolichos sesquipedalis*, while Chung and Ripperton[3] state that in Hawaii they use the soy bean (*Glycine hispida*) for large sprouts (up to 9 cm. long) and the mung bean (*P. aureus*) for small sprouts (4 cm. long).

MACROSCOPIC STRUCTURE.—The pubescent *plant* is more or less erect, up to 3 feet high; the *flowers* are small, yellow, in clusters. The rounded *pod* is up to 8 mm. long, with as many as 15 seeds. The seed is up to 5 mm. long, nearly as broad, and greenish in color.

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[1] Loc. cit.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[3] Hawaii Agr. Exp. Sta. 1929, Bul. 60.

Bean sprouts from the Chinese Quarter of New York, examined by the writers, were made from small red beans corresponding to the mung in structure. The stem and root together varied up to 8 cm. in length.

MICROSCOPIC STRUCTURE. Spermoderm.—The three layers are: (1) *palisade cells*, up to 55 μ high and 15 μ broad, with flattened outer ends, (2) *subepiderm* of delicate spool-shaped cells about 20 μ high and somewhat broader than high, and (3) *parenchyma.*

Hilum Cushion.—The cells of the small hilum cushion are packed with small *starch grains.*

Endosperm.—No cells evident.

Embryo.—The porous-walled cells of the *cotyledons* contain aggregate and semiaggregate starch grains up to 40 μ long, resembling those of the common bean but more irregular.

Sprouts.—The *epiderm* of the root and stem consists of longitudinally elongated, thin-walled cells and occasional narrow stomata on the stem end, the *inner epiderm* of the cotyledon of thin-walled, rounded-polygonal cells and numerous stomata, and the *outer epiderm* of thin-walled, rounded cells with here and there isolated cells triangular in shape, but no stomata. Starch is absent.

CHIEF STRUCTURAL CHARACTERS.—Seed 5 mm. long, green.

Palisade cells 55 μ high, subepidermal cells spool-shaped. Starch grains up to 40 μ. Tissues of sprouts delicate, starch absent. See also table p. 299.

CHEMICAL COMPOSITION.—The range in composition given below, compiled by Grimme[1] from analyses by Church, Dyboroski, and himself, although stated to be of seeds of *P. Mungo*, probably in some or all cases are of the true mung bean (*P. aureus* Roxb.); in any event

COMPOSITION OF MUNG BEAN

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Seeds						
Church:						
Min.	9.20	22.20	0.79	51.40	4.20	3.26
Max.	11.40	24.70	2.70	57.75	5.80	4.40
Agcaoili	14.70	20.44	0.93	56.56	4.36	3.01
Adriano	13.53	17.85	1.20	62.30	1.52	3.60
Pods						
Adriano	82.01	2.96	1.19	9.14	3.62	1.07

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[1] Z. Unters. Nahr.-Genussm. 1911, **21**, 547.

the beans of the group show no marked differences in composition. Agcaoili[1] states that the samples of beans analyzed by him were from *P. aureus*, and Adriano,[2] who analyzed both seeds and pods, doubtless derived his samples from the same species.

Bean Sprouts.—Adolph[3] gives an analysis of Chinese sprouts from Peiping, and Chung and Ripperton[4] give one analysis each of large and small sprouts from the Hawaiian market.

Composition of Bean Sprouts

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Adolph	92.50	2.77	0.35	2.78	1.07	0.53
C. and R.:						
Large sprouts	82.40	7.62	1.07	6.71	0.86	1.34
Small sprouts	93.77	2.52	0.08	2.98	0.34	0.31

Proteins.—Johns and Waterman[5] extracted with 5 per cent salt solution about 19 per cent of the 21.74 per cent of total protein (N × 6.25), calculated in both cases to the dry matter of the seed. From the brine extract, they isolated 0.35 per cent of *α-globulin* by adding ammonium sulphate to 0.15 to 0.20 saturation and 5.75 per cent of *β-globulin* by increasing the amount of ammonium sulphate to 0.65 saturation. The α-globulin coagulates from the slightly acid solution at 95 to 100° C., the β-globulin at 68 to 71° C. A small amount of *albumin* coagulating at 45° C. was isolated.

The *Ultimate Composition* of these proteins was as follows:

	α-Globulin	β-Globulin	Albumin
	%	%	%
Carbon	53.63	52.86	54.32
Hydrogen	6.86	6.89	6.95
Nitrogen	15.65	16.73	14.76
Sulphur	1.50	0.40	1.10
Oxygen	22.36	23.12	22.87
	100.00	100.00	100.00

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[1] Philippine J. Sci. 1916, **11**, 91.

[2] Philippine Agr. 1925, **14**, 57.

[3] Philippine J. Sci. 1926, **30**, 287.

[4] Loc. cit.

[5] J. Biol. Chem. 1920, **44**, 303.

Amino Acids of Mung Bean Proteins.—The percentages of basic amino acids in the proteins, as determined by Johns and Waterman,[1] follow:

	α-Globulin	β-Globulin
	%	%
Cystine	1.49	0.00
Arginine	5.13	7.56
Lysine	6.08	9.29
Histidine	3.30	2.03

Jones, Gersdorff, and Moeller[2] obtained the following figures for cystine and tryptophane respectively: total coagulable protein 0.59 and 1.62; α-globulin 1.68 and 2.03; β-globulin 0.44 and 1.18; albumin 1.34 and 2.26 per cent.

Nitrogen Distribution.—Results obtained by Johns and Waterman,[1] using Van Slyke's method, are tabulated below:

	α-Globulin	β-Globulin
	%	%
Humin N adsorbed by lime	2.56	1.84
Humin N in amyl alcohol extract	0.00	0.17
Cystine N	1.12	0.00
Arginine N	10.54	14.48
Histidine N	5.72	3.25
Lysine N	7.46	10.60
Amino N of filtrate	61.05	55.89
Non-amino N of filtrate	2.10	2.32
Amide N	9.42	11.76
	99.97	100.31

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[3] found 0.92 per cent, dry basis.

Mineral Constituents.—Chung and Ripperton[4] found in the large and small sprouts, the proximate analyses of which are given above, respectively, as follows: calcium 0.029 and 0.007; iron 0.0026 and 0.0007; phosphorus 0.023 and 0.038 per cent; alkalinity of ash 16.4 and 4.0 cc. normal acid per 100 grams of fresh vegetable.

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[1] Loc. cit.

[2] J. Biol. Chem. 1924, **62**, 183.

[3] Philippine Agr. 1932, **21**, 53.

[4] Loc. cit.

URD

Phaseolus Mungo L.

Fr. Haricot mungo. Ger. Mungobohne.

There has been some confusion in names, but *P. Mungo* is now considered to be the urd, and the related species *P. aureus*, the mung bean. The urd is a native of the Orient, where it is widely cultivated. Blasdale[1] states that it is grown by the Chinese in the vicinity of San Francisco for making bean sprouts (see Bean Sprouts, under Mung Bean).

MACROSCOPIC STRUCTURE.—The urd is distinguished from the mung bean chiefly by the more procumbent form of the *plant*, the longer *pods*, and the darker color of the *seeds*.

MICROSCOPIC STRUCTURE.—The **Spermoderm** resembles that of the mung bean. The tissues are: (1) *palisade cells*, up to 50 μ high and 15 μ broad, with flattened outer ends and 20 μ broad very dark cuticle, (2) *subepiderm* of spool-shaped cells, about 15 μ high, and (3) *parenchyma*.

Hilum Cushion.—The cells are packed with *starch grains*.

Endosperm.—No cells evident.

Embryo.—The *starch grains* of the cotyledons are of the common bean type, up to 27 μ long.

CHIEF STRUCTURAL CHARACTERS.—Seed similar to mung bean.

Spermoderm similar to that of mung bean. Starch of common bean type, up to 27 μ long. See also table p. 299.

CHEMICAL COMPOSITION.—The following are analyses by Blasdale[2] of green and red beans, by Church[3] of green beans, and by

COMPOSITION OF URD

	Water	Protein	Protein, pure	Fat	N-f. ext.	Starch	Sucrose	Sugars, reducing	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Blasdale:...										
Green....	8.83	22.64	21.88	1.34	59.82	48.54	0.00	0.00	4.52	2.85
Red.....	10.47	21.06	18.19	0.61	59.62	48.36	1.65	0.00	5.02	3.22
Church:										
Green....	10.8	22.2	......	2.7	54.1	......	......	....	5.8	4.4
Agcaoili....	9.21	18.30	......	4.88	62.49	......	......	....	4.89	4.23

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Loc. cit.

[3] Food Grains of India, London, 1886, p. 151.

Agcaoili[1] of an unknown variety, all stated to be from *P. Mungo*. Whether these are of the urd or the mung bean seems uncertain in view of the confusion in the literature.

Minor Mineral Constituents. *Copper.*—Seeds of var. *subtilibata* Fr. et Sav. 5.9 mg. per kilo, dry basis (Hirano and Mikumo).[2]

Enzymes.—Experiments by Nag and Banerjee[3] indicate that the ungerminated seeds of *P. Mungo* L. differ from the germinated in that they contain no proteolytic enzyme acting on peptones; neither, however, contains an enzyme acting on fibrin.

ADZUKI

Phaseolus angularis Willd. = *P. Mungo* var. *glaber* Roxb.

Although little known in the Occident the seeds of this legume form an important item in the diet of the Japanese and Chinese.

MACROSCOPIC STRUCTURE.—The species belongs to the group with lobed *leaflets* and yellow *flowers.* The *pod* is narrow cylindrical. The *seed* (Fig. 108) is small, varying from nearly isodiametric to somewhat elongated and flattened. Often the seeds are rounded-quadrilateral in outline. Dark wine-red is a common color, but there are buff, black, and mottled varieties. The hilum, reaching 3.5 mm., is covered with a white cushion bordered by a caruncle. It extends nearly to the chalaza end, hence the raphe joining the strophiole and the chalaza is relatively short.

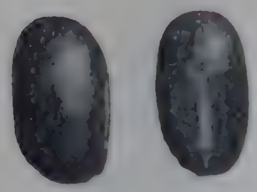

FIG. 108.—Adzuki. Seed. ×2. (A.L.W.)

MICROSCOPIC STRUCTURE. (Fig. 109).—Brief descriptions of the histology of the seed are given by Winton.[4]

Spermoderm (*S*).—The three layers are: (1) *palisade cells* (*pal*) up to 70 μ high and 16 μ broad, flattened at the outer ends, with lumens uniformly broadening to the inner ends; (2) *subepiderm* (*sub*) of typical spool-shaped cells, up to 15 μ high and 55 μ broad, without evident ribs; and (3) *parenchyma* (*p*) with few large intercellular spaces, the cells being largest in the middle layers and compressed in the inner.

The pigment that determines the color of the seed is present in the palisade cells of the epiderm, also in the thick-walled spongy parenchyma cells beneath the hilum.

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[1] Philippine J. Sci. 1916, **11**, 91.

[2] J. Pharm. Soc. Japan 1925, **525**, 992.

[3] Trans. Bose Res. Inst. Calcutta 1930–31, p. 14.

[4] Moeller: Mikros. Nahr.-Genussm., Berlin, 2 Aufl. 1905, p. 269; Micros. Veg. Foods, New York, 1st Ed. 1905 and 2nd Ed. 1916, p. 241.

Caruncle and Hilum Cushion.—The *palisade cells* of the caruncle are moderately elongated. These cells, as well as those of the hilum cushion, contain numerous small *starch grains*.

Endosperm (*E*).—This layer is not strongly developed but may be found in carefully cut sections.

Embryo.—Excepting the small isodiametric cells of the epiderms, the cells of the cotyledon (*C*) have indistinctly porous walls. Palisade cells are lacking. The *starch grains* are remarkable for their large size, up to 80 μ, and their obviously aggregate and semiaggregate structure to which the triangular or trefoil shape of many of them is due. Rifts are common, often extending in different directions from the center. The numerous aleurone grains (*al*) accompanying the starch in the mesophyl are round or elongated, up to 10 μ.

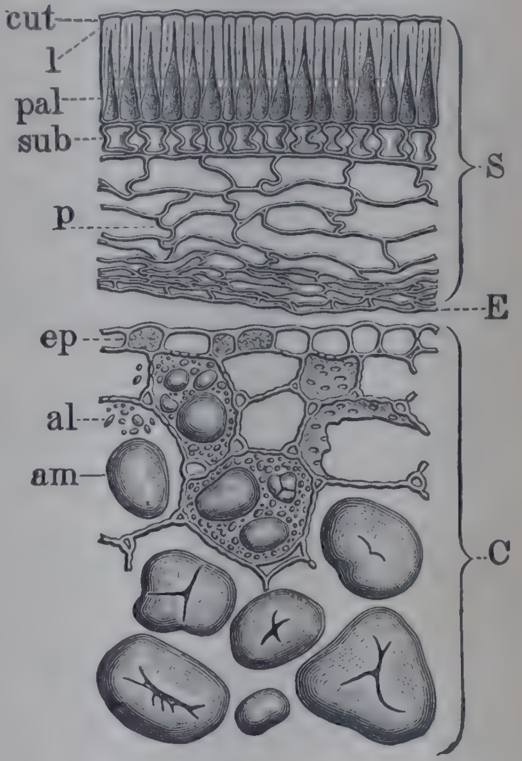

Fig. 109.—Adzuki. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, *p* parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, *al* aleurone grains and *am* starch grains of mesophyl. × 160. (K.B.W.)

Chief Structural Characters.—Seeds small, of various colors, with relatively long hilum extending to near chalaza end.

Palisade cells up to 70 μ high and 16 μ broad; subepidermal cells spool-shaped, up to 15 μ high and 55 μ broad. Cells of caruncle and hilum cushion with small starch grains. Endosperm inconspicuous, of a single layer. Starch grains large, up to 80 μ, many triangular or trefoil-shaped. See also table p. 299.

CHEMICAL COMPOSITION.—Analyses of 2 samples of the red adzuki bean, reported by Lindsey, Smith, and Beals,[1] contained on the average as follows:

Composition of Adzuki Beans (Lindsey et al.)

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
14.0	21.0	0.7	56.7	4.0	3.6

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[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

Proteins.—Osborne and Campbell[1] isolated from the adzuki bean two proteins: (1) *phaseolin,* identical in composition and properties with that of the common white bean, and (2) a second *globulin* which separated from the solution from which phaseolin had been precipitated by further addition of ammonium sulphate to complete saturation.

Jones, Finks, and Gersdorff[2] extracted with 5 per cent salt solution 16.7 per cent out of the 21.13 per cent of total protein present. From the extract, by precipitation with ammonium sulphate to different degrees of concentration, they separated two proteins which they designated α- and *β-globulin.* From a water extract they obtained a small amount of an *albumin.*

Takahashi and Itagaki,[3] in their examination of adzuki beans (under the name of *Adzukia subtrilobata*), found 27.5 per cent of protein of which 15 per cent consisted of two globulins (β_1 and β_2) and an albumin. Both of the globulins resemble the β-globulin of Jones, Finks, and Gersdorff.

Ultimate Composition.—The proteins isolated by the American investigators contained as follows:

	Osborne and Campbell		Jones, Finks, and Gersdorff	
	Phaseolin	Globulin	α-Globulin	β-Globulin
	%	%	%	%
Carbon	52.56	53.97	52.75	53.57
Hydrogen	6.97	7.01	6.97	6.79
Nitrogen	16.45	16.31	15.64	16.46
Sulphur	0.57	0.88	1.21	0.40
Oxygen	23.45	21.83	23.43	22.78
	100.00	100.00	100.00	100.00

Amino Acids of Adzuki Bean Proteins.—The percentages of basic amino acids as found by Jones, Finks, and Gersdorff,[2] and of cystine and tryptophane as found by Jones, Gersdorff, and Moeller[4] appear in the tables on the following page.

Takahashi and Itagaki[3] report in β_1- and β_2-globulin respectively: lysine 10.2 and 5.8 per cent.

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[1] J. Am. Chem. Soc. 1897, **19**, 509.

[2] J. Biol. Chem. 1922, **51**, 103.

[3] J. Biochem. Japan, 1925, **5**, 311.

[4] J. Biol. Chem. 1924, **62**, 183.

	α-Globulin	β-Globulin
	%	%
Cystine........	1.63	0.86
Tyrosine.......	....	2.13
Tryptophane....	+	+
Arginine........	5.45	7.00
Lysine.........	8.30	8.41
Histidine.......	2.25	2.51

	Total globulins	α-Globulin	β-Globulin	Total protein of alcohol extract	Total coagulable protein	Proteose
	%	%	%	%	%	%
Cystine.....	0.57	1.77	0.41	0.71	0.88	2.86
Tryptophane.	1.20	1.72	0.96	1.33	1.32	0.00

Nitrogen Distribution of Adzuki Bean Proteins.—Jones, Finks, and Gersdorff,[1] by Van Slyke's method, obtained as follows:

	α-Globulin	β-Globulin
	%	%
Humin N adsorbed by lime......................	1.40	0.84
Humin N in amyl alcohol extract.................	0.12	0.05
Cystine N..................................	1.21	0.60
Arginine N.................................	11.25	13.61
Lysine N...................................	10.20	9.75
Histidine N.................................	3.92	4.09
Amino N of filtrate............................	58.63	55.28
Non-amino N of filtrate........................	3.66	4.00
Amide N....................................	10.04	10.91
	100.43	99.13

According to Takahashi and Itagaki,[2] 52.2 and 61.2 per cent respectively of the total nitrogen of β_1- and β_2-globulin consists of monoamino nitrogen.

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[1] Loc. cit.

[2] Loc. cit.

CHINA BEAN or COW PEA

Vigna sinensis (L.) Endl. = *Dolichos sinensis* L.

Fr. Pois de vache. Ger. China-Bohne.

Notwithstanding the specific name which suggests oriental origin, the China bean, also known as the black-eyed bean and in the United States as the cow pea, is believed to be a native of central Africa. It is grown in the southern states of the United States for shell beans, being used both green and dry as a vegetable, also for forage. (See Forage Plants, Vol. I.)

MACROSCOPIC STRUCTURE.—Both the *plant* and the *fruit*, consisting of long (often 30 cm.), narrow pods, show the relationship with the common bean and not with the pea. As many as twenty-five seeds may occur in a pod, so distending it as to give a beaded appearance.

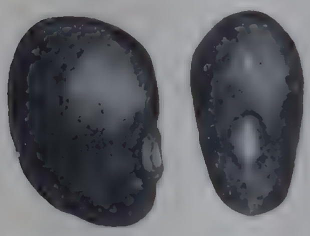

FIG. 110. — China Bean. Seed. × 2. (A.L.W.)

The *seeds* (Fig. 110) vary from kidney-shaped (up to 13 mm. long) to nearly spherical. There are black-, brown-, red-, yellow-, buff-, and white-seeded varieties. About the hilum the spermoderm is depressed and of a dark color, forming the black eye of dark seeds. The hilum itself is 3 to 3.5 mm. long, about half as broad. It is covered by a conspicuous white, raised cushion. The caruncle or rim of the cushion is brown and firm in texture. Both the strophiole and the micropyle are clearly evident under a lens.

MICROSCOPIC STRUCTURE (Fig. 111). **Spermoderm** (*S*).—Over the middle of the cotyledon the tissues are: (1) *palisade cells* (*pal*), up to 70 μ high and 15 μ broad, of which 10 μ is light line (*l*), with flat outer ends; (2) *subepiderm* (*sub*), up to 20 μ high and broad, of spool-shaped cells; and (3) *spongy parenchyma* (*p*), the inner layers of which are more or less compressed.

Mann[1] found that the lumens of the palisade cells of white varieties are distorted while those of dark varieties are symmetrical.

Beneath the hilum the spongy parenchyma is thick-walled, and the irregular-shaped cells contain dark contents.

Caruncle.—*Palisade cells*, up to more than 500 μ, with no visible contents, form the caruncle.

Hilum Cushion.—Thick-walled *spongy parenchyma* fills the central space over the hilum.

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[1] J. Agr. Res. 1914, 2, 33.

Embryo.—The thin-walled, isodiametric *mesophyl parenchyma* of he cotyledons (*C*) contains *starch grains* (*am*) up to 35 μ, most of vhich show rifts, whereas many show y their irregular swellings and their eportment with polarized light that hey are aggregates or semiaggregates.

Chief Structural Characters.—Seeds kidney-shaped or nearly globular, f various colors with a black rim about he hilum.

Palisade cells of spermoderm up to 70 μ high and 15 μ broad; subepidermal cells up to 20 μ high and broad. Palisade cells of caruncle up to more than 500 μ. Starch grains seldom reaching 35 μ, hence the smallest found in common egumes. See also table p. 299.

CHEMICAL COMPOSITION.—Five analyses of China bean, including black, yellow, black-eyed, and unnamed varieties, made at the New Jersey and North Carolina Experiment Stations from 1879 to 1882,[1] show the following range and average:

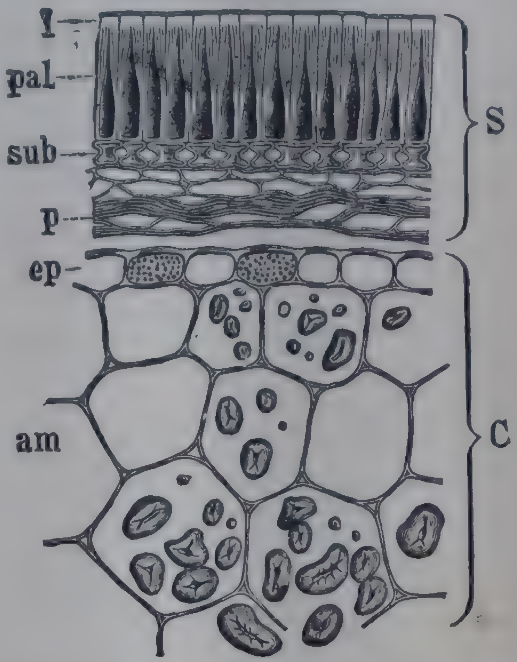

Fig. 111.—China Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *l* light line, *sub* subepiderm, *p* parenchyma. *C* cotyledon: *ep* outer epiderm, *am* starch parenchyma of mesophyl. × 160. (A.L.W.)

Composition of China Beans

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min........	10.01	19.31	1.28	50.51	3.37	2.94
Max........	20.85	23.02	1.55	61.99	5.03	3.35
Aver.......	**14.81**	**20.75**	**1.44**	**55.72**	**4.06**	**3.22**

Atwater and Bryant[2] summarize 13 analyses of dried beans, but the range is not materially different from that given above. A single analysis of the edible portion of green China beans showed: water 65.9, protein 9.4, fat 0.6, total carbohydrates 22.7, and ash 1.4 per cent.

Proteins.—Osborne and Campbell[3] isolated three distinct globulins: (1) *vignin*, forming the bulk of the total protein of the bean, which resembles legumin in its ultimate composition and physical propertie but differs from it in its amino acid content, (2) *phaseolin*, and (3) ar extremely *soluble globulin* that dissolves in very dilute salt solution.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1892, Bul. **11**.

[2] Ibid. 1906, Bul. **28** rev.

[3] J. Am. Chem. Soc. 1897, **19**, 494.

Ultimate Composition.—The following analyses are by Osborne anc Campbell:

	Vignin	Phaseolin	Soluble Globulin
	%	%	%
Carbon	52.64	52.27	53.25
Hydrogen	6.95	6.97	7.07
Nitrogen	17.25	16.69	16.36
Sulphur	0.50	0.50	1.11
Oxygen	22.66	23.57	22.21
	100.00	100.00	100.00

Amino Acids of Vignin.—By Fischer's hydrolysis method, Osborne and Heyl[1] obtained the following percentages:

PRODUCTS OF HYDROLYSIS OF VIGNIN (OSBORNE AND HEYL)

	%
Glycocoll	0.00
Alanine	0.78
Valine	0.29
Leucine	6.73
Aspartic acid	2.94
Glutamic acid	12.84
Tyrosine	2.03
Phenylalanine	4.69
Proline	4.41
Tryptophane	+
Arginine	6.04
Lysine	3.77
Histidine	2.71
Ammonia	2.18
	49.41

Part of the deficiency shown in the above table, as explained by the authors, is accounted for by (1) amino acid mixture, weighed but not separated 6.98 per cent, (2) one-half of the undistilled residue 3.49 per cent, and (3) 20 per cent of the amino acids which escaped esterification 7.58 per cent.

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[1] Am. J. Physiol. 1908, **22**, 362.

Jones, Gersdorff, and Moeller[1] found in vignin: cystine 0.52 and tryptophane 1.65 per cent.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[2] found 8.58 per cent, dry basis.

Colors.—Mann[3] found (1) a pale yellow to copper red basic color in the parenchyma of the spermoderm and (2) pigmented areas of either anthocyanin or melanin-like substances. He also notes that if the anthocyanin is red it is due to an acid condition but if blue or black to alkaline.

Minor Mineral Constituents. *Copper.*—Black-eyed peas 7.36 mg. per kilo (Satterfield and Jones).[4]

BLACK-EYED LONG BEAN

Dolichos melanophthalmus DC. = *D. monochalis* Brotero

Ger. Schwarzäugige Langbohne.

Harz[5] describes this seed briefly, M. Kondo[6] in detail with six illustrations.

MACROSCOPIC STRUCTURE.—Judging from Kondo's illustrations, the seed resembles closely the China bean in form but is somewhat larger.

MICROSCOPIC STRUCTURE.—Harz states that the *palisade cells* in the thinner part of the spermoderm are 22 to 24 μ high; Kondo states that they are 35 to 40 μ high, but his cuts, which are drawn to scale, show them as about 60 μ high or nearly the height of the palisade cells of the China bean. Kondo's measurements of the *subepidermal cells* and the *starch grains* also correspond closely with those of the China bean.

HYACINTH BEAN

Dolichos Lablab L. = *D. cultratus* Thunb. = *D. purpureus* Lindl. =
Lablab vulgaris Savi = *L. cultratus* DC.

Fr. Dolic d'Egypte. Ger. Lablab.

Other names for this legume are lablab and Egyptian bean. Known in the temperate zone chiefly as an ornamental vine, in the tropics it yields both string and shell beans for the table. De Candolle believes that its original habitat is India, where it still is much used for food.

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[1] J. Biol. Chem. 1924, **62**, 183.

[2] Philippine Agr. 1931, **21**, 53.

[3] Loc. cit.

[4] J. Elisha Mitchell Sci. Soc. 1932, **48**, 16.

[5] Samenkunde, Berlin, 1885, p. 735.

[6] Z. Unters. Nahr.-Genussm. 1913, **25**, 1.

MACROSCOPIC STRUCTURE.—As in *Vigna*, the white or purple papilionaceous *flowers* have an incurved keel and style, but the style is hairy only on the inner side below the stigma and on the outer side it is not extended beyond the stigma. The *pod* is rather short (up to 9 cm.), flattened, pointed, smooth except on the edges, and contains about four seeds.

The *seed* (Fig. 112) is ellipsoidal, up to 1.2 cm. long, buff, red, brown, or black, with a hilum covered by a conspicuous caruncle and a white cushion running fully one-third the distance about the circumference. It should be noted that while in most common legumes the hilum, if not central, is nearer the micropyle end, in this seed the arrangement is reversed. Strophiole and micropyle, both evident under a lens, are accordingly at the two opposite ends of the seed.

MICROSCOPIC STRUCTURE (Figs. 113 and 114).—The structure is briefly described by Harz[1] and by Tschirch and Oesterle[2] and in detail by Kondo.[3] The description which follows is based on the authors' examination of (1) white-flowered, buff-seeded, and (2) purple-flowered, black-seeded varieties.

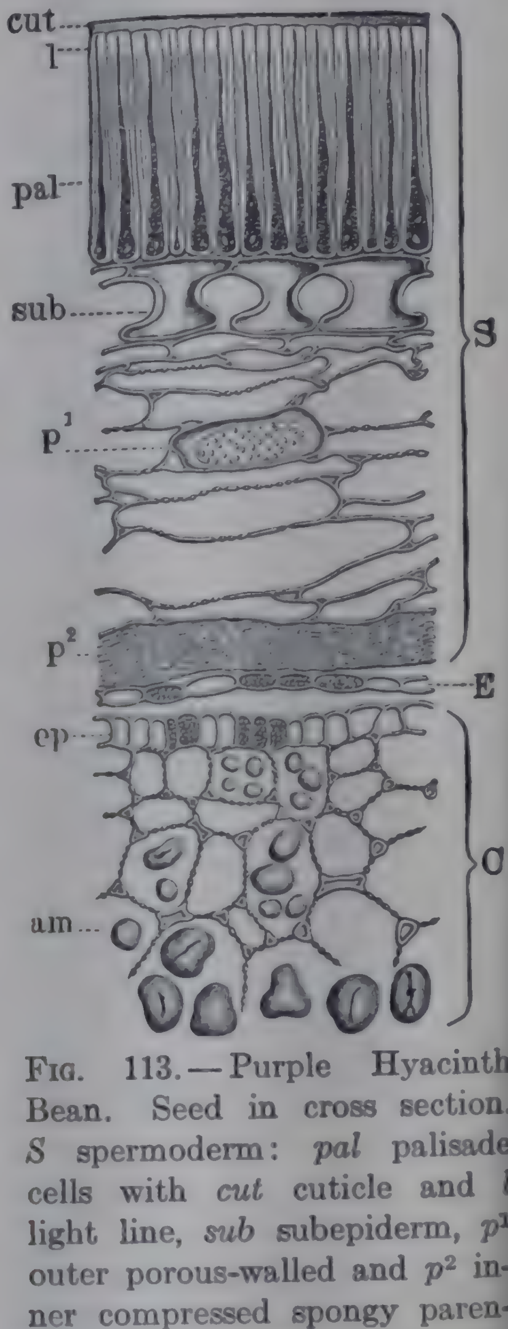

FIG. 113.—Purple Hyacinth Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, p^1 outer porous-walled and p^2 inner compressed spongy parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, *am* starch grains of mesophyl. × 160. (K.B.W.)

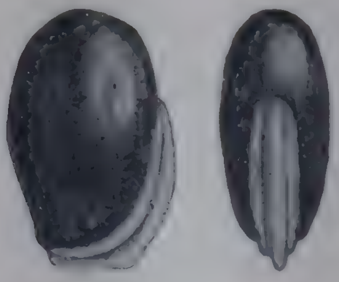

FIG. 112.—Hyacinth Beam. Seed. × 2. (A.L.W.)

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[1] Samenkunde, Berlin, 1885, p. 736.

[2] Anat. Atlas, Leipzig, 1900, p. 215.

[3] Z. Unters. Nahr.-Genussm. 1913, **25**, 21.

Spermoderm (Fig. 113, *S*).—Sections cut through the center of one side show: (1) *palisade cells* (*pal*), up to 155 μ high and 15 μ broad, with wedge-shaped cavities containing yellow or brown granules and crystals, a thick brown cuticle (*cut*), and a light line (*l*) about 13 μ broad; (2) *subepiderm* (*sub*) of large spool-shaped cells, up to 70 μ high and 60 μ broad; and (3) *parenchyma*, porous and large-celled in the middle portion (p^1), small-celled, very spongy, and compressed in the inner portion (p^2).

Beneath the hilum the *subepiderm* (see Fig. 114) forms a thick, loose tissue of variously shaped cells, with dark contents. Circling about the sclerenchyma group (*sc*) are elongated, thin-walled cells.

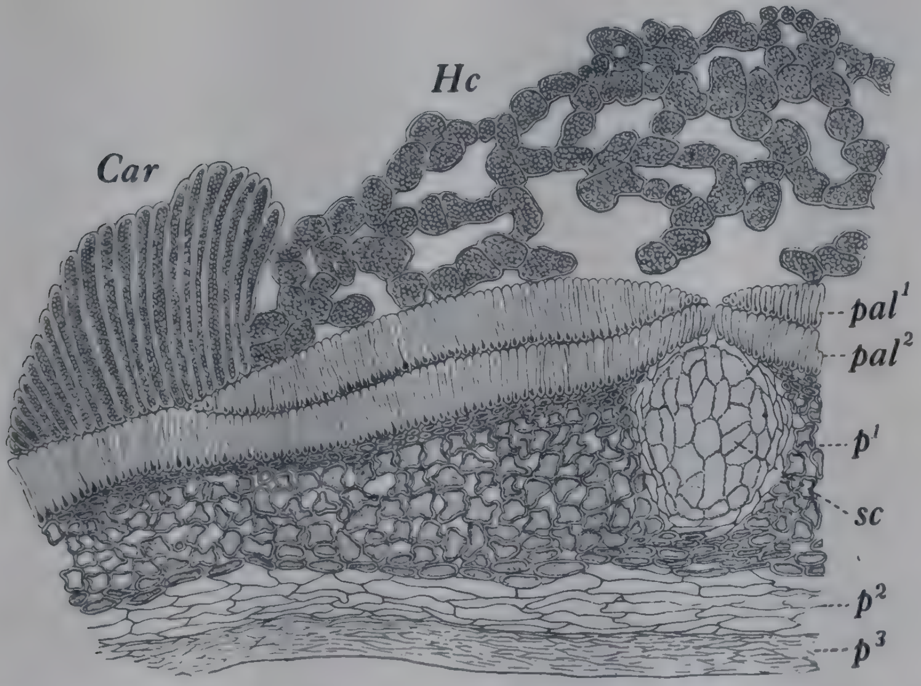

FIG. 114.—Purple Hyacinth Bean. Cross section through hilum. *Car* palisade cells of caruncle and *Hc* spongy parenchyma of hilum cushion, both containing starch grains. Spermoderm: *pal*^{1}, *pal*^{2} double palisade layer, p^1 modified outer parenchyma, *sc* sclerenchyma group surrounded by thin-walled cells, p^2 outer and p^3 inner thin-walled parenchyma. × 54. (K.B.W.)

Caruncle and Hilum Cushion.—The *palisade cells* (Fig. 114, *Car*) of the caruncle are strongly developed, often reaching a height of over 500 μ. These, as well as the rounded cells (*Hc*) of the spongy parenchyma of the cushion, are closely packed with rounded or polygonal *starch grains* about 15 μ in diameter.

Endosperm (Fig. 113, *E*).—In seeds examined by the writers, this formed a single layer of *aleurone cells*. In Kondo's material it was not evident.

Embryo.—The cotyledons (Fig. 113, *C*) are without palisade cells. The walls of the *mesophyl* are porous. *Starch grains* (*am*), up to 35 μ, occur in the mesophyl together with granular protein matter and fat. In addition to ellipsoidal and reniform grains, there are rounded-triangular or trefoil-shaped grains showing clearly their compound nature. Rifts may or may not be present.

Chief Structural Characters.—Seed flattened, ellipsoidal, light or dark, hilum with spongy cushion and caruncle extending fully one-third the distance about the edge.

Palisade cells up to 155 μ high and 15 μ broad, with thick cuticle and light line; subepidermal cells spool-shaped, up to 70 μ high and 60 μ broad; parenchyma porous in the middle portion. Endosperm of a single aleurone layer. Caruncle and hilum cushion with rounded starch grains up to 15 μ. Mesophyl of cotyledon porous, with starch up to 35 μ. See also table p. 299.

CHEMICAL COMPOSITION.—In the following table are a single analysis of the dried beans by Blasdale[1] and the range of 7 analyses compiled by Grimme[2] from various sources; also an analysis of the fresh beans by Agcaoili:[3]

Composition of Hyacinth Bean

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Dried:						
Blasdale	12.1	24.4	1.5	57.4	1.2	3.4
Grimme:						
Min.	10.20	18.21	0.78	43.64	1.20	2.52
Max.	12.90	25.66	2.80	62.06	7.73	3.54
Fresh:						
Agcaoili	87.56	3.32	0.25	6.19	1.73	0.95

Proteins.—The results given herewith are by Narayanaturti and Ramaswami.[4] By successive extraction with the solvents named, they obtained the following results in terms of nitrogen in the total nitrogen: water 72.8, 4 per cent sodium chloride 10.21, cold 70 per cent ethyl alcohol 1.27, hot 70 per cent ethyl alcohol 2.54, and 0.4 per cent sodium hydroxide 12.77 per cent.

Ultimate Composition.—The chief protein, *dolichosin*, a globulin, contained: carbon 51.83, hydrogen 8.51, nitrogen 15.5, sulphur 0.27, phosphorus 0.55, and oxygen 23.34 per cent.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Z. Unters. Nahr.-Genussm. 1911, **21**, 547.

[3] Philippine J. Sci. 1916, **11**, 91.

[4] Biochem. J. 1930, **24**, 1650.

Amino Acids of Dolichosin.—The figures for cystine, lysine, and tryptophane, given below, are averages of results by different methods agreeing within reasonable limits; the other figures were obtained in each case by the same method:

	%
Cystine	0.99
Tyrosine	5.10
Tryptophane	2.53
Arginine	8.11
Lysine	6.63
Histidine	0.86

Nitrogen Distribution in Dolichosin.—The following results are in terms of nitrogen in the total nitrogen: humin 1.33, cystine 0.79, arginine 16.84, lysine 8.20, histidine 1.50, amino 56.35, non-amino 3.77, amide 10.49, total 99.27 per cent.

HORSE GRAM

Dolichos biflorus L.

Sanskrit Kulattha. Hindi Kulthi.

This species is grown in India and has been introduced into the United States.

MACROSCOPIC STRUCTURE.—Seeds flattened, up to 6 mm. long and 4 mm. wide.

MICROSCOPIC STRUCTURE.—No data.

CHEMICAL COMPOSITION.—An analysis by Narayana[1] shows, dry basis: protein 26.40, pure protein 21.93, fat 2.32, nitrogen-free extract 62.29, fiber 5.48, and ash 3.51 per cent.

Proteins.—The globulin isolated by Narayana[1] yielded on hydrolysis, in the ash and water-free substance: cystine 1.81; tyrosine 6.68; tryptophane present; arginine 6.02 (Van Slyke), 7.11 (direct); lysine 7.64; and histidine 0.84 per cent.

The *Nitrogen Distribution* was as follows: acid-insoluble humin N 1.31, soluble humin N 0.05, cystine N 0.43, arginine N 12.30, lysine N 9.24, histidine N 1.44, mono-amino N 63.74, non-amino N 1.76, and amide N 10.43 per cent.

Enzymes.—According to Menon and Rao[2] the content of *urease* in horse gram is similar to that in soy bean.

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[1] J. Indian Inst. Sci. 1930, **13A**, 153.

[2] Indian J. Med. Res. 1932, **19**, 1077.

JACK BEAN

Canavalia ensiformis DC. = *C. gladiata* DC.

Several species of *Canavalia* are grown in the tropics and sub-tropics for their seeds and to some extent for the pod in the snap stage. The jack bean, or Chickasaw Lima, in the southern states of the United States serves as food for both man and cattle.

Canavalia obtusifolia DC. is less widely known.

Chinese mixed pickles put up in tins in Hongkong often contain slices of the flattened green pod of the jack bean or a related species of *Canavalia*.

Like several other leguminous seeds, the jack bean has been used as a coffee substitute and adulterant.

MACROSCOPIC STRUCTURE.—Both the trifoliate *leaves* and the inconspicuous white or purplish papilionaceous *flowers* resemble those of other common members of the group, but the flattened, tough *pod* is strikingly different, being of large size (often 35 cm. long and 5 cm. broad) and conspicuously four-ribbed along the ventral edge. Two of the ribs flank the somewhat depressed suture while two more are on opposite sides of the thickest part of the pod. The dorsal edge is well rounded and narrower than the ventral. When full grown but still turgid the walls of the pod are over 5 mm. thick with a leathery outer coat and a similar inner coat (endocarp) lining the cavity.

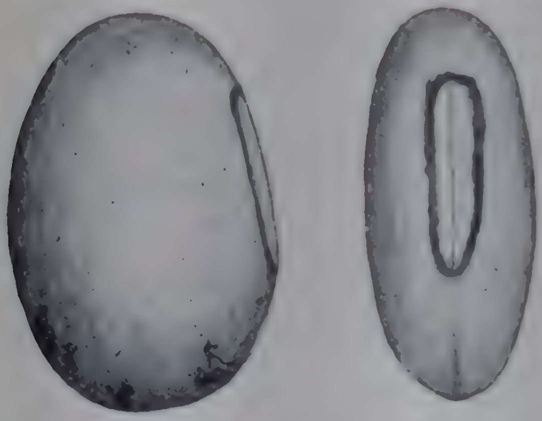

Fig. 115.—Jack Bean. Seed × 2. (A.L.W.)

The somewhat flattened ovate *seeds* (Fig. 115) are arranged with the longer axis at right angles to that of the pod but in the same plane. This necessitates the funiculus joining the seed at an angle since the hilum is on one of the longer edges of the seed, although nearer the micropyle end than the chalaza.

In the variety commonly grown in the United States, the *seed* is white, up to 2 cm. long, and so uniformly rounded as to resemble a bird's egg. The hilum is often 8 mm. long. About the hilum is a conspicuous dark red border, but only traces of a caruncle and hilum cushion are evident. Of the three samples examined by Kondo,[1] one from Madagascar conforms quite closely to this description, reaching 2.2 cm. in length. Of the two others, both from Japan, one was red, up to 3 cm. in length, the other white, up to 2.7 cm. in length. In addition to being larger than the American and Madagascar beans, both, as appears from Kondo's cuts, are pointed at the chalaza end and the hilum is longer and more nearly in the center of the edge. These marked differences, coupled with differences in the histological structure, suggest that possibly two botanical varieties are represented.

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[1] Z. Unters. Nahr.-Genussm. 1913, **25**, 26.

MICROSCOPIC STRUCTURE OF GREEN POD. **Pericarp.**—The large green pod found in Chinese pickles is analogous in structure to the snap bean but the layers are more strongly developed and the whole is coarse and tough. The tissues are: (1) *epicarp* (Fig. 116) of isodiametric ground cells, somewhat larger crystal cells, and stomata, also finely warty, jointed hairs and capitate hairs with multicellular heads; (2) *hypoderm* of large, tangentially elongated collenchyma cells, one or more thick; (3) *mesocarp* of large, rounded cells, in the outer part with thick, porous walls, containing large starch grains, often over 30 μ, also elongated secretion cavities and fibro-vascular bundles accompanied by crystal cells; (4) *fiber layer*, often ten or more fibers thick; (5) *parenchyma* of narrow, much-elongated cells, tangentially arranged, with thin cellulose walls, forming a layer of considerable thickness; (6) *inner mesocarp* of small cells, containing small starch grains and often single crystals; and (7) *endocarp* of small, thin-walled, polygonal cells.

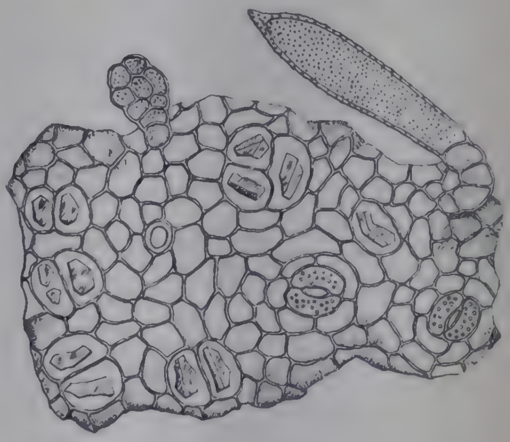

FIG. 116.—Jack Bean. Epicarp of immature fruit in surface view showing pointed and capitate hairs, hair scar, crystal cells, and stomata. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE OF SEED (Fig. 117).—Moeller,[1] briefly, and Kondo,[2] very fully, describe the histology of the mature seed. In the following description are given the results of our own study of American beans, noting the main points of divergence from Moeller's and Kondo's results.

Spermoderm (*S*).—Not including a possible inner epiderm the layers are: (1) *palisade cells* (*pal*), up to 220 μ high and 30 μ broad, each with narrow lumen—excepting the globular enlargement at the inner end—thin cuticle (*cut*), and narrow light line (*l*); (2) *subepiderm* (*sub*) of several rows of thick-walled, spool- or bone-shaped cells, up to 60 μ high and 55 μ broad, passing into (3) *spongy parenchyma*, large-

[1] Mikros. Nahr.-Genussm. Berlin, 2. Aufl. 1905, p. 284.

[2] Loc. cit.

celled with porous walls in the outer portion (p^1), small-celled, thin-walled, and compressed in the inner portion (p^2).

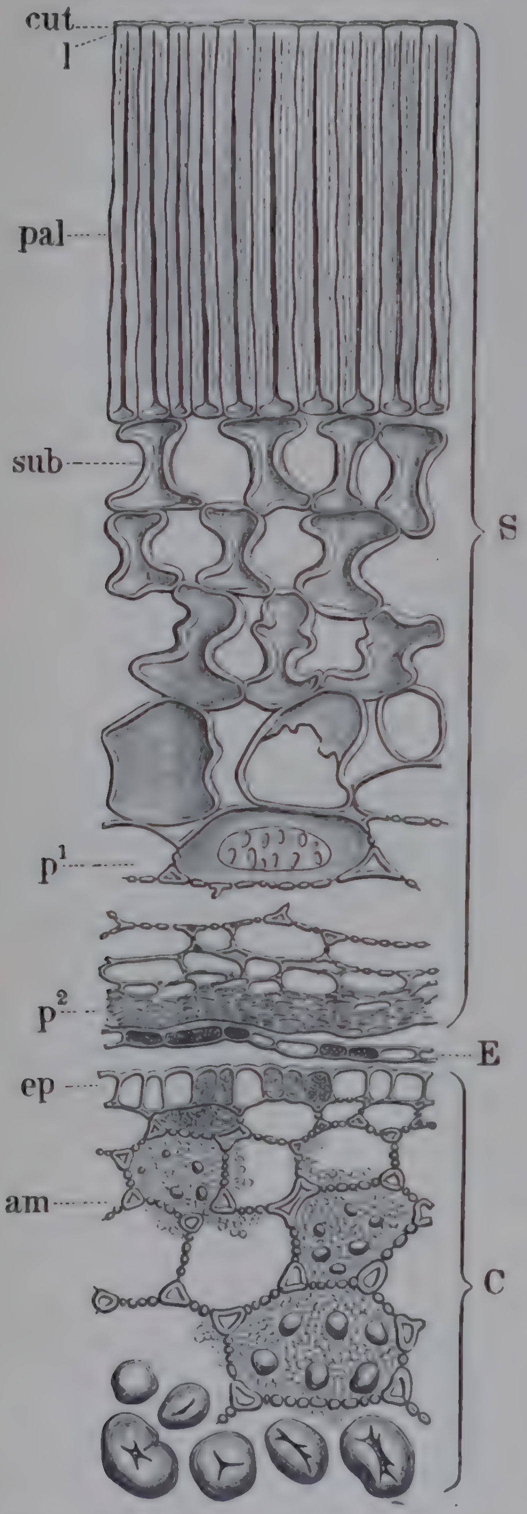

Fig. 117.—Jack Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, p^1 outer thick-walled pitted spongy parenchyma, p^2 inner thin-walled compressed spongy parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, *am* starch grains embedded in protein matrix. × 160. (K.B.W.)

Kondo, in his cut of a red Japanese specimen, does not show a globular enlargement of the *palisade cell* lumen, but his dimensions of all three specimens conform closely with the above except that he found that the palisade cells of both the red and white Japanese specimens reached 260 μ. The occurrence of several rows of cells in the *subepiderm* is remarkable. So thick is the outer large-celled portion of the *spongy parenchyma* as to necessitate omission in Fig. 117 of several rows of cells.

Beneath the hilum, as in other common legumes, there are present a double palisade layer and a group of sclerenchyma cells immediately beneath the hilum slit embedded in spongy parenchyma, which is here bulky. Kondo notes that in the Japanese red and the Madagascar white beans the spongy parenchyma cells are much branched and thick-walled with brown contents, whereas in the Japanese white beans the intercellular spaces are smaller and the walls thinner.

Caruncle and **Hilum Cushion.**—Only traces present.

Endosperm (*E*).—Kondo calls attention to the single layer of *aleurone cells* overlooked by Moeller.

Embryo.—The cells of the cotyledons (*C*) are more or less isodiametric throughout and not differentiated as palisade cells beneath the inner epiderm. In the American beans examined by the writers, as well as in the Madagascar beans examined by Kondo, the walls are strongly thickened and porous with small intercellular spaces, but in both samples of Japanese beans examined by Kondo the walls are thin and the intercellular spaces are large, causing the beans to float in water.

Only *fat* and finely granular *protein matter* occur in the epiderms and one or more cell layers beneath. *Starch grains*, increasing in size and numbers from without inward, occur in the remaining cells embedded in the protein matter. They reach a maximum of 55 μ in the American beans. Kondo found the maximum in red and white Japanese beans and white Madagascar beans to be respectively 59, 52, and 70 μ. Rifts are often present. The common forms are ellipsoidal and reniform.

CHIEF STRUCTURAL CHARACTERS.—Pod large, flattened, up to 35 cm. long, ventral edge four-ribbed, broader than two-ribbed dorsal edge. Seed variable in size, shape, color, and position of hilum according to the variety; American bean well rounded, white, with hilum much nearer micropyle than chalaza end, surrounded by red border.

Epicarp with jointed, warty and capitate hairs; hypoderm of collenchyma cells; mesocarp thick-walled with large (30 μ) starch grains; fiber layer thick, adjoined by layer of elongated parenchyma. Palisade cells of spermoderm up to 220 μ high (260 μ in Japanese beans) and 30 μ broad; subepidermal cells spool- or bone-shaped, up to 60 μ high and 55 μ broad, forming several rows; outer spongy parenchyma large-celled, porous, inner small-celled, thin-walled. Cells of cotyledon with thick, porous walls (thin in Japanese beans); starch grains up to 55 μ (70 μ in Madagascar beans). See also table p. 299.

CHEMICAL COMPOSITION.—A proximate analysis of the seed by Greshoff, Sack, and Van Eck of the Haarlem Colonial Museum[1] gave: water 15.06, protein 20.12, fat 1.60, nitrogen-free extract 43.04, fiber 9.67, and ash 2.84 per cent.

The composition of the seed, hulls, and pod with seeds, as given in the Report for 1895 of the Mississippi Experiment Station, follows:

COMPOSITION OF JACK BEAN (MISSISSIPPI EXP. STA.)
(Results in percentages of dry matter)

	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%
Seed	26.85	2.99	56.90	9.88	3.38
Hulls	2.44	0.52	48.51	43.89	4.64
Pod with seeds	17.76	3.06	56.08	19.31	3.79

Analyses of the seed, hulls, and the green plant, on the original water basis, follow:[2]

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[1] König: Chemie mensch. Nahrs.-Genussm. Berlin, 1903, **1**, 1484.

[2] See Piper: U. S. Dept. Agr. 1920, Circ. **92**.

COMPOSITION OF JACK BEAN

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Seed:						
Texas Exp. Sta. (1914)	11.06	23.82	3.52	50.79	8.05	2.77
Shrewsbury (1917)*	15.50	27.60	3.20	45.20	5.40	3.10
Imperial Inst. (1913)	14.40	25.00	2.70	48.40	6.80	2.70
Imperial Inst. (1915)	12.70	26.09	3.90	46.91	7.60	2.80
Boname (1911)†	13.00	25.62	2.32	47.94	7.90	3.22
Barnstein (1914)‡	13.26	31.51	2.18	41.99	8.59	2.47
Hulls:						
Boname (1911)†	15.20	5.00	0.64	15.47	57.91	5.78
Green plant:						
Hawaii Exp. Sta. (1911)	76.81	5.21	0.48	8.44	6.36	2.70

* Bul. Dept. Agr. Trinidad and Tobago 1917, **16**, 224. † Agr. prat. pays chauds 1911, **10**, 371. ‡ Landw. Vers.-Stat. 1914, **85**, 113.

Proteins.—In beans containing 23 per cent of protein Jones and Johns[1] separated two globulins, *concanavalin* and *canavalin*, and an *albumin* of the legumelin type. Concanavalin separated from the brine extract on adding ammonium sulphate to 0.6 saturation; canavalin separated on complete saturation of the filtrate from the concanavalin precipitate. The albumin was obtained from the filtrate from the canavalin after dialyzing by heating to 62° C.

According to Sumner[2] three globulins are present: (1) *concanavalin A*, present in moderate amount and separating as bispheroid crystals, soluble only in concentrated salt solution, (2) *concanavalin B*, present in minute amount and forming needle crystals slowly soluble in 10 per cent salt solution, and (3) *canavalin*, forming the bulk of the protein matter, separating as spheroids, soluble in 1 per cent salt solution.

Ultimate Composition.—The three proteins found by Jones and Johns[3] contained as follows:

	Concanavalin	Canavalin	Albumin
	%	%	%
Carbon	53.28	53.26	53.24
Hydrogen	7.02	7.03	7.00
Nitrogen	16.45	16.72	16.38
Sulphur	1.10	0.48	0.88
Oxygen	22.15	22.51	22.50
	100.00	100.00	100.00

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[1] J. Biol. Chem. 1916, **28**, 67.

[2] Ibid. 1919, **37**, 137.

[3] Loc. cit.

Amino Acids of Jack Bean Proteins.—Determinations of cystine and tryptophane by Jones, Gersdorff, and Moeller[1] show respectively: total globulin 0.99 and 2.29; concanavalin 1.57 and 3.36; canavalin 0.40 and 0.21; albumin 1.48 and 4.30 per cent. Results on cystine, tyrosine, and tryptophane by Sumner and Graham,[2] employing Folin and Looney's methods, show respectively: concanavalin A 0.4, 5.2, 2.2; concanavalin B 3.2, 9.4, 2.3; and canavalin 1.0, 5.5, 0.24 per cent.

Nitrogen Distribution.—Jones and Johns[3] determined the nitrogen distribution in canavalin and the albumin with results as follows:

	Canavalin	Albumin
	%	%
Humin N......	0.28	0.23
Amide N.......	1.41	1.16
Basic N........	3.17	3.73
Non-basic N....	11.55	11.18
	16.41	16.30

Nitrogenous Bases.—Kitagawa and Tomita[4] and Kitagawa and Tomiyama[5] have found in the jack bean a nitrogenous substance, giving the ninhydrin reaction. An enzyme present in liver (not arginase) splits off a portion of the nitrogen as urea.

Fat.—Grimme[6] obtained by ether extraction 2.81 per cent of fat, or over one per cent more than that found by Greshoff, and the following values of the fat:

Sp. gr. 15° C.	Refr. index 25° C.	Solid. Pt.	Sapon. No.	Iodine No.	Fatty acids, total	Fatty acids, titer	Unsapon. matter
		° C.			%	° C.	%
0.9169	1.4757	– 7	186.5	86.1	92.78	29	1.29

Phosphorus-Organic Compounds.—Sumner,[7] by successive extraction of the seeds with petroleum ether, acetone, toluene, and 95 per cent alcohol, obtained a mixture of phosphatides resembling cytozyme in its action in the coagulation of blood.

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[1] J. Biol. Chem. 1924, **62**, 183.

[2] Ibid. 1925, **64**, 257.

[3] Loc. cit.

[4] Proc. Imp. Acad. Japan 1929, **5**, 380.

[5] J. Biochem. Japan 1929, **11**, 265.

[6] Pharm. Zentralh. 1911, **52**, 1141.

[7] Compt. rend. soc. belg. biol. 1922, 26.

Enzymes.—Of particular interest is the *urease* which, according to Mateer and Marshall,[1] is present in fifteen times the amount found in the soy bean and consequently may be profitably prepared from this bean. Jacoby[2] has shown that the urease is of a colloidal nature.

Mineral Constituents.—In the seeds and hulls respectively Boname[3] reports: potash 1.351 and 2.898, lime 0.218 and 0.450, magnesia 0.238 and 0.083, and phosphoric acid 0.715 and 0.071 per cent.

VELVET BEAN

Stizolobium Deeringianum Hort.

Various species and numerous varieties of *Stizolobium* are grown in the tropics and sub-tropics for green forage and for the seeds, the latter being ground for stock food. The velvet bean, often sold by seedsmen under the name *Dolichos multiflorus*, is the variety best known in the United States.

MACROSCOPIC STRUCTURE.—The *plant* is bean-like with trifoliate *leaves* and large white or purple *flowers*, the keel of which is usually twice or more the length of the standard. Although the leaves and the short *pod* are hairy, they do not have the stinging hairs of cowitch (*S. pruriens* Medic.). The *seed* (Fig. 118) varies from nearly spherical to ovoid, up to 1.5 cm. long, and is cream-color, blotched with chocolate-brown. A raised white rim, often 1 mm. high, forming the caruncle, borders the hilum which is 7 mm. long and is bare in the center.

MICROSCOPIC STRUCTURE (Fig. 119).—The structure of the seed hitherto has escaped investigation.

Spermoderm (*S*).—This part of the seed is much like that of the hyacinth bean, consisting of: (1) *palisade cells* (*pal*), up to 115 μ high and 25 μ broad, with broad light line (*l*) but thin cuticle (*cut*); (2) *subepiderm* (*sub*), of spool-shaped cells up to 45 μ high and 40 μ broad, with radial walls in close contact at the top and strongly thickened in the middle; and (3) *parenchyma*, spongy throughout, with large cells, often beaded, in the outer portion (p^1), and small, thin-walled cells in the inner portion (p^2).

Exceptionally thick walls characterize the spongy parenchyma beneath the hilum. The individual cells are of various shapes and lack colored contents.

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[1] J. Biol. Chem. 1916, **25**, 297.

[2] Biochem. Z. 1926, **167**, 21.

[3] Loc. cit.

Caruncle.—In cross section this is somewhat fan-shaped with cells radially elongated, thick-walled, and empty.

Endosperm (*E*).—A single layer of cells.

Embryo.—Throughout the cotyledons (*C*) the cells are nearly isodiametric. Excepting those of the *epiderms*, the cell walls are porous. Minute aleurone grains are the visible contents of the epiderms and often the subepiderm. Further inward *starch grains*, reaching 40 μ in the interior, occur in a protein matrix. They are irregularly ovate, often blunt pointed, the hilum, as brought out by polarized light, being usually in the narrow end with an excentricity of about 1:6. They resemble ginger starch, but the occurrence of two short-curved hilum rifts suggests maranta starch.

The presence of *starch grains* of the excentric type in a legume closely related to others with the typical ellipsoidal or reniform grains supports the writers' contention that these latter forms consist merely of aggregates.

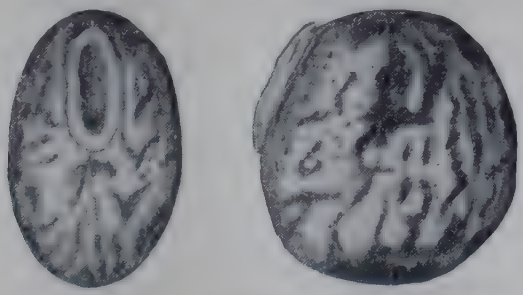

Fig. 118.

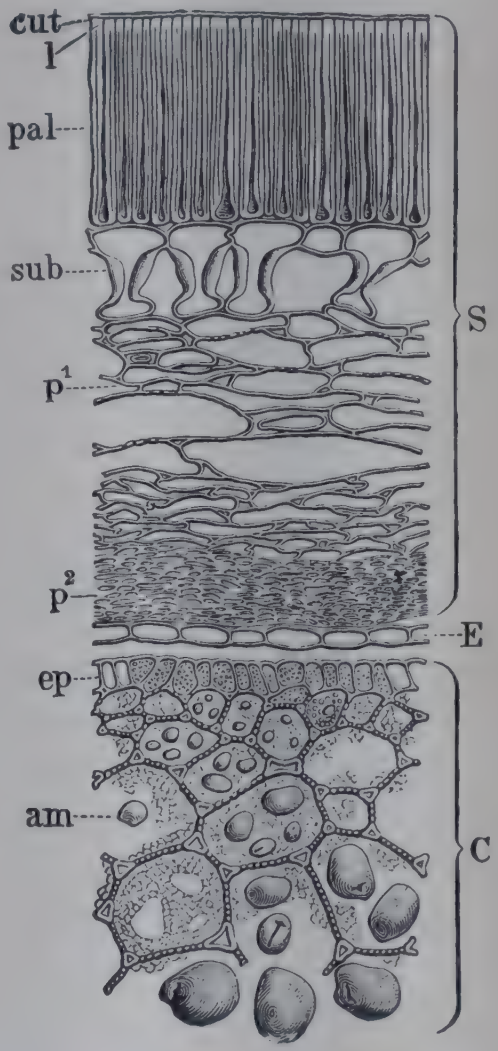

Fig. 119.

Velvet Bean. Seed. × 2. (A.L.W.)

Velvet Bean. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, p^1 outer and p^2 inner spongy parenchyma. *E* endosperm. *C* cotyledon: *ep* outer epiderm, *am* starch grains embedded in protein matrix. × 160. (K.B.W.)

Chief Structural Characters.—Seed nearly spherical or moderately elongated (1.5 cm.), blotched, with rim (caruncle) about hilum.

Palisade cells up to 115 μ high and 25 μ broad; subepiderm of spool-shaped cells up to 45 μ high and 40 μ broad, with thick radial walls; cells of caruncle conspicuous but empty; starch cells of cotyledons porous; starch grains up to 40 μ, pointed ovate, with strongly excentric hilum usually in small end, embedded in protein matrix.

CHEMICAL COMPOSITION.—Analyses of the shelled and unshelled beans, reported by Lindsey, Smith, and Beals,[1] follow:

Composition of Velvet Beans (Lindsey et al.)

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Seeds only.....	1	7.0	25.2	5.8	52.6	6.0	3.4
Seeds and pods	4	9.7	17.9	4.4	49.6	14.1	4.3

Miller[2] reported the following results on the Early Speckled which closely agree with those on other varieties examined: protein 20, fat 6.5, carbohydrate (largely starch) 30, alcohol extract 12 to 13, and ash 2.8 to 2.9 per cent.

Proteins.—Johns and Finks[3] separated from the Chinese velvet bean (*S. niveum*) a globulin, *stizolobin*, which they believed to be the principal protein. Jones and Johns[4] isolated what appeared to be the same protein from the Florida variety of *S. deeringianum*.

Johns and Waterman[5] studied the proteins in the Georgia velvet bean, stated to be a sport of the Florida variety. The total protein in the bean was about 23 per cent, and the protein soluble in 3 per cent salt solution was about 15 per cent, of which the mixed proteins coagulating on boiling the slightly acid extract were about 13 per cent. From the salt solution extract they isolated three proteins: (1) *α-globulin*, precipitated by 0.4 saturation with ammonium sulphate, coagulable at 70 to 78° C.; (2) *β-globulin*, precipitated by 0.6 to 0.7 saturation with ammonium sulphate, coagulable at 90 to 100° C.; and (3) an *albumin*, obtained by coagulation of the aqueous extract from which the globulins had been removed by dialysis, coagulable at 54 to 62° C. The yield of the three proteins was only respectively 3, 1.25, and 0.75 per cent. Whether the same methods were later applied to Chinese and Florida velvet beans does not appear.

Ultimate Composition.—The average composition of the three proteins of the Georgia bean, as found by their discoverers, follows:

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[1] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[2] Alabama Col. Sta. Rep. 1919, p. 34.

[3] J. Biol. Chem. 1918, **34**, 429.

[4] Ibid. 1919, **40**, 435.

[5] Ibid. 1920, **42**, 59.

	α-Globulin	β-Globulin	Albumin
	%	%	%
Carbon	53.08	53.15	53.40
Hydrogen	6.82	6.79	6.76
Nitrogen	16.66	17.28	15.86
Sulphur	0.91	0.46	1.01
Oxygen	22.53	22.32	22.97
	100.00	100.00	100.00

Amino Acids of Velvet Bean Proteins.—Johns and Finks[1] determined only the basic amino acids in stizolobin. Their results were confirmed by Jones and Johns,[2] who subjected their preparation to hydrolysis and determined all the amino acids by Fischer's esterification method with the following results:

PRODUCTS OF HYDROLYSIS OF STIZOLOBIN (JONES AND JOHNS)

	%
Glycocoll	1.66
Alanine	2.41
Valine	2.88
Leucine	9.02
Serine	0.67
Cystine	1.13
Aspartic acid (Dakin method)	9.23*
Glutamic acid	14.59
Hydroxyglutamic acid	2.81
Tyrosine	6.24
Phenylalanine	3.10
Proline	4.00
Tryptophane	+
Arginine	7.14
Lysine	8.51
Histidine	2.27
Ammonia	1.55
	77.21

* Usual method 5.7%.

The following results were obtained by Johns and Waterman[3] in the two globulins and the albumin isolated by them:

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[1] Loc. cit.

[2] Loc. cit.

[3] Loc. cit.

	α-Globulin	β-Globulin	Albumin
	%	%	%
Cystine	1.03	0.89	1.92
Arginine	7.19	8.18	6.13
Histidine	1.24	3.38	0.82
Lysine	8.32	8.51	8.20

Tests for tryptophane gave strong reactions in α-globulin and albumin but none in β-globulin. This is the first vegetable protein found to contain no tryptophane.

Jones, Gersdorff, and Moeller[1] studied the proteins of both the Chinese and the Georgia velvet bean and obtained the following figures for cystine and tryptophane:

	Chinese	Georgia				
	Stizolobin	Total globulin	α-Globulin	β-Globulin	Total coagulable protein	Albumin
	%	%	%	%	%	%
Cystine	1.55	1.76	3.26	0.66	2.65	2.69
Tryptophane	1.36	1.23	2.26	0.00	1.95	2.46

Nitrogen Distribution in Velvet Bean Proteins.—The following results were obtained by Van Slyke's method:

NITROGEN DISTRIBUTION IN VELVET BEAN PROTEINS (JOHNS AND WATERMAN)

	α-Globulin	β-Globulin	Albumin
	%	%	%
Humin N adsorbed by lime	1.42	1.46	1.80
Humin N in amyl alcohol extract	0.17	0.04	0.00
Cystine N	0.73	0.61	1.41
Arginine N	13.85	15.39	12.35
Histidine N	2.01	5.34	1.41
Lysine N	9.56	9.55	9.85
Amino N of filtrate	59.22	52.38	64.25
Non-amino N of filtrate	4.27	4.28	0.34
Amide N	8.99	10.85	9.08
	100.22	99.90	100.49

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[1] J. Biol. Chem. 1924, **62**, 183.

Dihydroxyphenylalanine.—Miller[1] separated from the Georgia velvet bean crystalline 3, 4-dihydroxyphenylalanine, a substance related to adrenalin, which may prove injurious to cattle if the beans are fed in large quantities and over a long period. Reactions of this substance, but no actual crystals, were obtained with the Yokohama (*S. hassjoo* P. et T.) and Lyon (*S. niveum* Kuntz) velvet beans, indicating that it is a characteristic constituent of the genus. It was not found in other leguminous seeds tested although Torquati[2] had previously isolated it from the sprouted germs and the pods of *Vicia faba.*

Enzymes.—In experiments by Miller[3] the enzymic action of the seed coat resembled so closely that of artificial dioxides and peroxides as to suggest the actual presence of a peroxide.

Mineral Constituents.—Miller[4] reports the following results on the Early Speckled variety: calcium 0.13 to 0.15, magnesium 0.14 to 0.16, phosphorus 0.4 to 0.31, and chlorine 0.021 per cent.

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[1] J. Biol. Chem. 1920, **44**, 481.

[2] Arch. farm. sperm. **15**, 213, 308.

[3] Plant Physiol. 1929, **4**, 507.

[4] Alabama Col. Sta. Rep. 1919, p. 34.

FRUITS OF THE MALLOW FAMILY

(*Malvaceæ*)

Characteristic of this family are the mucilaginous tissues. One species, okra, is grown for its edible pericarp, but several, including cotton, yield industrial fibers with edible seeds as a by-product. Roselle (*Hibiscus Sabdariffa* L.) has a fleshy calyx from which are prepared acid beverages and jellies. This species is described under Fruits. The roots of the marsh mallow (*Althæa officinalis* L.) and other allied plants, being rich in mucilage, are used in medicine. The name marsh mallow applied to the well-known confection is a misnomer as the peculiar consistency is due to gums.

OKRA

Hibiscus esculentus L. = *Abelmoschus esculentus* Moench.

Fr. Gombaut. Sp. Gombo. It. Ombretta commestible. Ger. Okra.

Okra or gumbo, a vegetable of secondary importance in the North, is much grown in the South for its immature fruits which, used in soups, impart a peculiar mucilaginous consistency. Investigations carried out by De Candolle led to the conclusion that Africa, not Asia as formerly thought, is its original habitat.

MACROSCOPIC STRUCTURE.—As is true of cotton, the *flower* is large and showy with numerous narrow bractlets (2 to 3 cm. long) outside of the five-cleft calyx. The large petals are dull yellow, with a red eye at the base, surrounding five stamens united to form a column about the five styles.

Although usually stated to be five-celled, the ovary and pod in the modern highly cultivated varieties are quite commonly seven-celled. When mature the *fruit* is a dry capsule, dehiscing along the ribs which correspond to the backs of the cells. At the tender edible stage the *pod* is slender, tapering, 12 cm. or more long, with pronounced ribs. It is borne on a rather thick peduncle several centimeters long.

The amphitropous *seeds* are about 5 mm. in diameter, kidney-shaped approaching round, black with minute gray ridges. The hilum is large, round, and situated in the slightly incurved part of the edge. As is true of cottonseed, the thin, broad cotyledons are curiously folded. The end of the radicle is within the slight elevation adjoining the hilum.

MICROSCOPIC STRUCTURE.—Kraus[1] describes the pericarp of several members of the family, Lohde[2] includes the spermoderm of *H. Trionum* L. in his monograph, and Kondo[3] fully describes and illustrates the structure of okra seed.

Pericarp (Fig. 120).—At the edible stage there are five well-marked layers: (1) *epicarp* (*epi*) of thin-walled, polygonal cells, stomata, unicellular hairs (t^1), and multicellular hairs on unicellular bases (t^2); (2) *hypoderm* (*hy*) of thin-walled, polygonal cells, some containing oxalate rosettes; (3) *mesocarp* of loose parenchyma cells, containing chlorophyl grains and small grains of transitory starch often in twins and triplets, interspersed with oxalate rosette cells as in the hypoderm, large mucilage cells, and fibro-vascular bundles; (4) *crystal layer*, each cell with a single prismatic crystal; and (5) *endocarp* of fibers, mostly transversely arranged, and stomata.

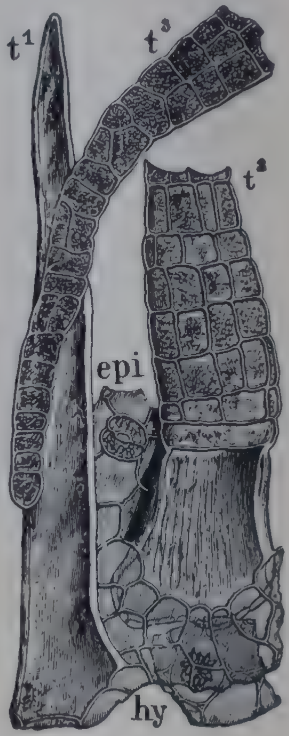

FIG. 120. — Okra. Immature pericarp. *epi* epicarp: t^1 unicellular hair, t^2 base and t^3 tip of multicellular hair, *hy* hypoderm with rosette crystal. × 160. (K.B.W.)

The *unicellular hairs* (t^1) are thin-walled, broad, and may reach nearly 1 mm. in length. More remarkable are the *multicellular hairs* (t^2, t^3) which often exceed 1 mm. in length. The basal cell is broad and thick-walled, while the remainder of the hair consists of an aggregate of small, often nearly cubical cells, varying in number from four or five wide next to the basal cell to a single cell at the apex. These multicellular forms predominate on the older fruit, the unicellular forms on the young fruit.

The *endocarp fibers* are variously arranged, often with a parquetry effect. When several layers are present, the fibers may or may not cross. At a more mature stage the guard cells of the stomata as well as the fibers are thickened and pitted.

Spermoderm.—At the edible stage little differentiation other than radial elongation of the palisade cells is evident. At maturity the structure is as follows: (1) *outer epiderm* of thin-walled, rounded cells without hairs or stomata; (2) *brown cells* with thick walls, occurring mostly singly below the ridges; (3) *beaker cells* with inner walls and base of radial walls thickened and colored brown; (4) *palisade cells*, up to 175 μ high, as in cottonseed except that the globular cavity is midway between the two ends and the light line is about 20 μ from the outer end; (5) *brown parenchyma*, several cells thick, thick-walled with brown contents; and (6) colorless *compressed cells.*

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[1] Prings. Jahr. wiss. Bot. 1866–7, **5**, 83.

[2] Inaug. Dis., Leipzig, 1874.

[3] Ber. Ohara Inst. landw. Forsch. 1925, **2**, 580.

Perisperm.—This consists of a single row of cells, as in cottonseed, but the cells are distinctly pitted, not merely fringed.

Endosperm.—Kondo found several rows of cells; the writers found only one in the material available.

Embryo.—*Parenchyma cells,* containing aleurone grains and fat, and procambium bundles make up the tissues. Resin cavities, such as occur in cottonseed, are not present although addition of concentrated sulphuric acid gives a slight pink color.

CHIEF STRUCTURAL CHARACTERS.—Pods elongated, five- or more celled with as many ribs; seeds kidney-shaped, nearly round, consisting largely of a tough spermoderm and folded embryo.

Epicarp hairs partly unicellular, partly multicellular with unicellular base and several rows of cells between base and tip; mesocarp with mucilage cells; endocarp of transverse fibers and stomata. Spermoderm much as in cottonseed, but hairs are absent, third layer is developed as beaker cells, and lumen of palisade cells is midway between ends. Cotyledons without resin cavities.

CHEMICAL COMPOSITION.—Analyses of the entire green fruit, as used in soups and stews, have been reported by Zega[1] in Serbia and Atwater and Bryant[2] in the United States. It would appear from the water content that Zega's material was gathered at a more advanced stage of development. Samples of canned okra, packed at New York, Philadelphia, Baltimore, and New Orleans, were examined by McElroy and Bigelow.[3] Since the manufacture of an edible oil from the seed has been suggested, the analyses of the mature seed and pod, made by Kilgore,[4] are of interest. See table next page.

Fatty Oil of Seed.—The oil obtained from the seeds, like other oils of the family, reacts with Halphen's reagent. Jamieson and Baughman[5] examined in detail a large sample of the oil expressed by them from Avery Island seed with a total content of 15.60 per cent and in less detail three smaller samples.

Physical and Chemical Values.—The values obtained on the large sample together with some others (in parentheses) obtained on the smaller samples follow: specific gravity 25°/25° 0.9172 (0.9160 to

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[1] Chem. Ztg. 1900, **24**, 871.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[3] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, 1129.

[4] N. Carolina Agr. Exp. Sta. 1893, Bul. **90b**.

[5] J. Am. Chem. Soc. 1920, **42**, 166.

COMPOSITION OF OKRA

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Salt
		%	%	%	%	%	%	%
Fresh Fruit:								
Zega........	4							
Min.......		78.86	3.18	0.38	11.07	0.80	1.26	.....
Max......		82.21	4.74	0.48	13.64	1.61	1.58	.....
Aver......		**80.74**	**4.15**	**0.42**	**12.12**	**1.15**	**1.41**	.....
A. and B....	2							
Min.......		87.4	1.2	0.1	5.3*	....	0.5	.....
Max......		92.9	2.0	0.4	9.5*	....	0.7	.....
Aver......		**90.2**	**1.6**	**0.2**	**7.4***	**3.4†**	0.6	.....
Canned Fruit:								
McE. and B.	4							
Min.......		94.02	0.54	0.04	2.50	0.35	0.30‡	0.04
Max.......		94.88	0.90	0.24	3.30	1.37	0.45‡	1.30
Aver......		**94.35**	**0.71**	**0.09**	**2.95**	**0.66**	**0.41‡**	**0.83**
Ripe seed:								
Kilgore.....	1	7.06	21.25	15.11	24.42	26.35	5.81	.....
Ripe pod:								
Kilgore.....	1	6.00	4.74	0.79	32.88	47.59	8.00	.....

* Includes fiber. † 1 sample. ‡ Salt-free.

0.9187), refractive index at 25° C. 1.4702 (1.4692 to 1.4695), saponification number 195.2 (195.5 to 195.6), iodine number 95.2 (93.2 to 100.3), Reichert-Meissl number 0.26, Polenske number 0.23, acetyl number 21.4 (11.5 to 23.9), acid number 1.42 (0.34 to 0.66), soluble acids 0.14 per cent (0.09 to 0.12), insoluble acids 96.20 per cent (95.9 to 96.27), unsaturated acids 67.33 per cent, saturated acids 29.22 per cent, and unsaponifiable matter 0.37 per cent. The values of the insoluble, saturated, and unsaturated acids were respectively: saponification number 210.6, 215.6, 199.2, and iodine number 97.3, 5.7, 137.9. The solidifying point of the insoluble acids (titer test) was 38.5° C.

Composition of Okra-Seed Oil.—The authors named above give the following figures based on their data:

	%
Glycerides of:	
Arachidic acid	0.05
Stearic acid	2.75
Palmitic acid	27.23
Oleic acid	43.74
Linolic acid	26.62
Unsaponifiable matter	0.37
	100.76

Mineral Constituents.—Zega[1] obtained the following results expressed in percentages of the fresh vegetable:

K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2
% 0.042	% 0.58	% 0.100	% 0.010	% 0.043	% 0.034	% 0.06

Minor Mineral Constituents. *Iron.*—Fruit, 5 samples, 72 to 140, aver. **101** mg. per kilo, dry basis (Remington and Shiver).[2]

Manganese.—Fruit, 5 samples, 36.5 to 62.5, aver. **48.3** mg. per kilo dry basis (Remington and Shiver).[2]

Copper.—Fruit, 8 samples, 5.9 to 13.4, aver. **9.4** mg. per kilo, dry basis (Remington and Shiver).[2]

[1] Loc. cit.

[2] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

FRUITS OF THE NIGHTSHADE FAMILY

(*Solanaceæ*)

To this family belong not only the potato and tobacco but also several fruit vegetables, notably the tomato, garden peppers, and egg plant. The strawberry tomato (*Physalis*) and nightshade (*Solanum nigrum*) are of minor importance. Paprika, the dried mature fruit of a species which also yields garden peppers, and cayenne pepper, a related species, are described in Volume III under Spices.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *flowers* have normally five-lobed sepals and petals and two-celled ovaries and fruit, but there are exceptions due to cultivation. The corolla is usually plaited in the bud and in the garden species more or less wheel-shaped when open. Except for a few hairs on the egg plant, the surface of the *fruit* is practically smooth and lustrous. The numerous *seeds* are borne on central placentæ, except at the top of the fruit of certain species (e.g., garden peppers). Characteristic of the campylotropous seeds is their irregularly lens-shaped form, their tough spermoderm, bulky endosperm, and coiled embryo with elongated cotyledons and radicle.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—The *epicarp* or skin consists usually of polygonal cells, more or less thick-walled, beaded, and sclerenchymatized, containing in some species (e.g., egg plant and nightshade) the characteristic color of the fruit in solution. In cayenne pepper the cells approach the quadrilateral in form and are arranged in rows; in some varieties of capsicum the walls are sinuous as well as thickened. In the large fruit of the egg plant the epicarp cells are small (about 35 μ), whereas in the small fruits of the strawberry tomato and nightshade they are large (80 to 100 μ or more).

A *hypoderm* of polygonal, beaded or collenchymatously thickened cells, several thick, characterizes the large fruited species.

The *mesocarp* is characterless except for the red oil drops and the giant cells of the peppers.

The *endocarp* in the peppers has groups of thickened, sclerenchymatized, and beaded cells.

Capsaicin, a pungent substance, occurs in peppers beneath the cuticle of the dissepiment.

Spermoderm.—Only one layer, the *outer epiderm*, is conspicuou This is characterized by the sclerenchymatous thickening of the wal which in the tomato is restricted to radially arranged rods, mistake even by recent authors for hairs, while in the other species it is strongl developed in the inner and radial walls, forming in egg plant, pepper and nightshade deeply sinuous folds and in strawberry tomat more uniform swellings so thick as practically to obliterate the ce cavity. Delicate rods occur on the outer half of the walls in the nigh shade. Warts are scattered over the inner wall in the garden pepper and paprika, while cavities occur in the middle lamella at the oute ends of the radial walls in the egg plant, and to a lesser degree in paprika appearing like pores in cross section.

Endosperm and **Embryo** consist of small polygonal cells containin minute aleurone grains and fat.

COMPARATIVE CHEMICAL COMPOSITION.—The tomato i strongly acid and distinctly saccharine; the pepper is neither but i more or less hot; the egg plant is bland and characterless.

TOMATO

Solanum Lycopersicum L. = *Lycopersicum esculentum* Mill.

Fr. Tomate. Sp. Tomate. It. Pomidoro. Ger. Liebesapfel.

Several species of the genus *Lycopersicum* grow wild in western South America from one of which has been derived the cultivated tomato. The continent that has given us our leading subterranean vegetable, the potato, and one of our best beans, the Lima, also justly claims credit for this acid vegetable that is valuable not only for salads but also for sauces, pickles, and sweetmeats. It stands first in importance among canned vegetables and is the chief constituent of tomato catsup. Numberless varieties have been developed by cultivation, differing greatly in size and form and in color from yellow to deep red. The currant tomato now appears to be a distinct species (*L. pimpinellifolium* Dunal).

MACROSCOPIC STRUCTURE.—All varieties have exceedingly smooth, lustrous skin with the scar of the style at one end and the prominent peduncle scar at the other end in a depression. The *fruit* of the wild form and the cherry tomato has two cells, but large-fruited cultivated varieties usually have more. The numerous *seeds* are borne on central placentæ, apparently embedded in a jelly which disappears on washing and drying, leaving the seeds with a dense coat of false hairs. The leathery spermoderm encloses the bulky endosperm within which is embedded the curved embryo consisting of elongated cotyledons and a somewhat shorter radicle.

MICROSCOPIC STRUCTURE. Pericarp (Fig. 121).—Four layers are present: (1) *epicarp* (*epi*) of bright yellow, beaded, polygonal cells; (2) *hypoderm* (*hy*) of similar but larger cells; (3) *mesocarp* of rounded cells, containing chromatophores, forming a ground tissue through which run the vascular bundles; and (4) *endocarp* of thin-walled parenchyma.

Passerini[1] refers to two coloring substances, one red and crystalline, the other yellow and amorphous. Later two carotenoids were isolated, *lycopersicine* (*lycopene*) and *carotene*. Duggar[2] noted the occurrence of the lycopene as needle-shaped crystals. Carotene was also shown to be present. See Introduction to Vegetables.

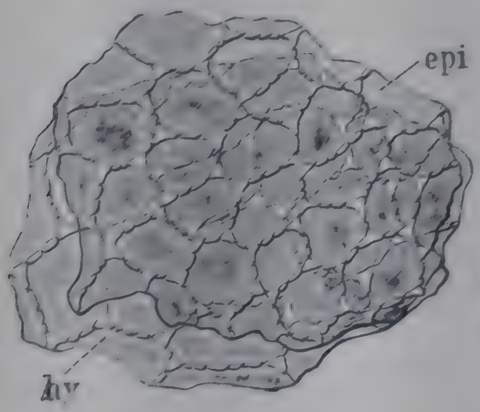

FIG. 121.

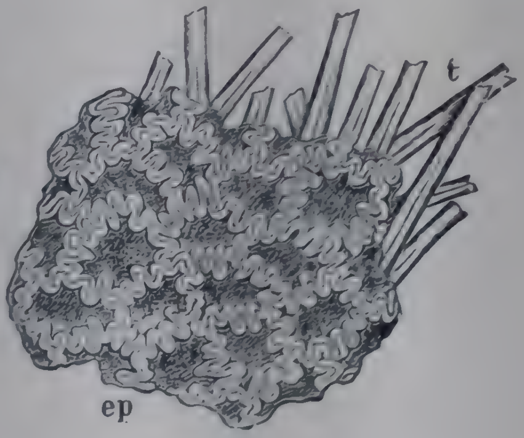

FIG. 122.

FIG. 121.—Tomato. *epi* epicarp and *hy* hypoderm of pericarp in surface view × 300. (A.L.W.)

FIG. 122.—Tomato. *ep* outer epiderm of spermoderm with *t* false hairs, from below. × 160. (A.L.W.)

The vessels of the *vascular bundles* are largely narrow spiral. At the stem end occur also pitted vessels and bast fibers.

Spermoderm (Fig. 122; Fig. 123, *S*).—Only the *outer epiderm* (*ep*) shows cellular structure at maturity, the remaining layers forming a structureless band. At the base the epidermal cells are isodiametric with thick sinuous, sclerenchymatized walls. The appendages which cover the seed on drying were formerly thought to be hairs but the writers[3] have shown that they are rods which stiffen the otherwise thin outer part of the radial walls of the radially elongated, gelatinous epidermal cells.

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[1] Staz. sper. agr. ital. 1890, **18**, 545.

[2] Washington Univ. Studies 1913, **1**, 22.

[3] Micros. Veg. Foods, New York, 2d Ed. 1916, p. 411.

Perisperm (Fig. 123, *N*).—Ordinarily this is not evident but the cells expand on treatment with Javelle water.

Endosperm (Fig. 123, *E*) and **Embryo** (*Ra*) are practically the same as in paprika, cayenne, egg plant, and other solanaceous plants. The cells of both contain exceedingly small aleurone grains and fat.

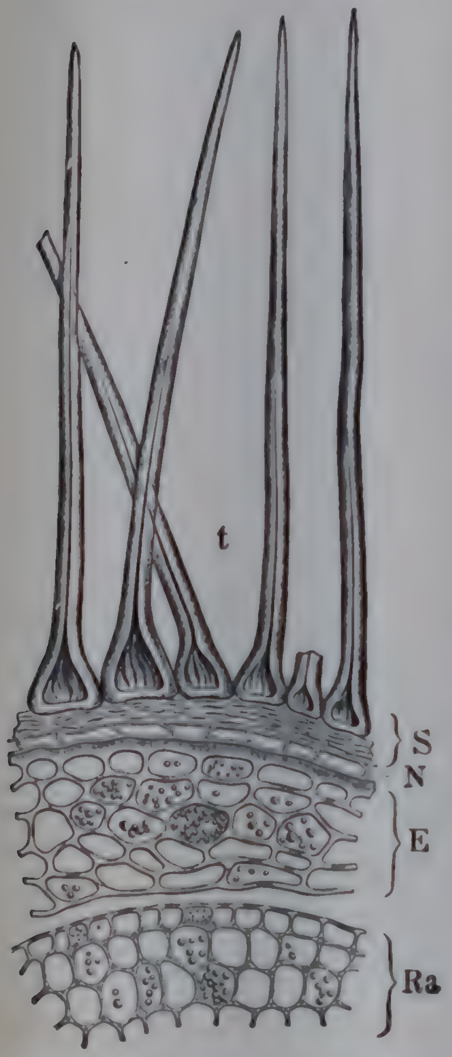

FIG. 123.—Tomato. Seed in cross section. *S* spermoderm: *t* false hairs. *N* perisperm. *E* endosperm. *Ra* radicle. × 160. (A.L.W.)

CHIEF STRUCTURAL CHARACTERS.—Fruit smooth, red or yellow, usually over two-celled; style scar small, peduncle scar large, in depression; seeds numerous, gelatinous, with false hairs.

Epicarp and hypoderm cells polygonal, beaded; mesocarp cells rounded. Inner part of outer epiderm of spermoderm with sinuous sclerenchymatized walls; outer part with rods on radial walls forming false hairs. Endosperm and embryo containing minute aleurone grains and fat.

CHEMICAL COMPOSITION.—In the analysis of 63 varieties of tomatoes by Patterson,[1] the dry matter ranged from 3.10 to 4.52, the sugars from 1.76 to 3.52, and the acid, calculated as citric, from 0.52 to 1.81 per cent. The range in composition of 3 samples of Minnesota tomatoes, analyzed by Snyder,[2] and of a number of samples of California tomatoes, analyzed by Saywell and Cruess,[3] follows on the next page.

Faltin[4] gives the average composition of 15 samples of Hungarian tomatoes as follows: water 94.58, total sugars as invert 3.23, acid calculated as citric 0.32, and ash 0.55 per cent.

Passerini[5] analyzed ripe and unripe fruit and the different parts. Brissi and Gigli[6] found that the pulp constituted 85.4 per cent of the whole fruit and contained 4.73 per cent of solids of which 3.74 per cent was soluble. Bigelow[7] examined the soluble pulp (juice) of 60 samples

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[1] Maryland Agr. Exp. Sta. Rep. 1889, p. 67.

[2] Minnesota Agr. Exp. Sta. 1899, Bul. **63**, 513.

[3] Fruit Prod. J. 1933, **12**, 177.

[4] Kisérletügyi Közlemények 1932, **35**, 136.

[5] Staz. sper. agr. ital. 1890, **18**, 545.

[6] Ibid. 1890, **18**, 5.

[7] J. Ass. Off. Agr. Chem. 1917, **3**, 1.

COMPOSITION OF TOMATOES

	Water	Protein	Amides	Fat	Acid*	Dextrose	Levulose	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
Snyder:											
Min....	93.61	0.80	0.36	0.05	0.38	1.03	1.03	1.60	......	0.32†	0.54
Max...	93.93	0.90	0.40	0.05	0.49	1.12	1.13	1.73	......	0.37†	0.69
S. and C.:											
Min....	93.00	0.85	.....	.....	0.35‡	3.30§		.....	0.01‖	......	.....
Max...	94.00	1.00	.....	.....	0.40‡	3.50§		0.05	0.06‖	......	.....

* Calculated as citric. † Insoluble in acid. ‡ *p*H 4.0–4.2. § Ratio dextrose to levulose 1.17:1.24. ‖ Acid hydrolyzable carbohydrate 0.10–0.30%.

representing 9 varieties grown near Washington, D. C. Analyses by the authors named appear in the following table:

COMPOSITION OF WHOLE TOMATOES AND PARTS
(Results on dry basis)

	Water	Protein	Fat	N-f. ext.	Acids	Sugars	Fiber	Ash
	%	%	%	%	%	%	%	%
Passerini:								
Whole green..	93.50	11.25	11.73*	61.64	48.53†	12.68‡	7.83	8.05
Whole ripe...	91.01	11.48	7.02*	50.62	9.07†	41.54‡	18.14	12.73
Skin (1.3%)..	59.50	1.85	97.05		......	....	......	0.80
Insoluble pulp.	93.65	15.15	74.41		......	....	......	10.44
Soluble pulp..	97.56	21.80	52.72		......	....	......	25.48
Seeds (2.5%).	46.30	25.40	70.16		......	....	......	4.40
Brissi and Gigli:								
Insoluble pulp.	....	25.01§	21.13*	....	......	....	34.39	7.96
Soluble pulp..	....	14.06‖	......	....	14.03	46.68¶	......	10.96
Bigelow:								
Soluble pulp								
Min........	93.58	....	......	....	6.4**	35.1††		
Max.......	96.09	....	......	....	17.0**	65.7††		

* Includes color. † Includes undetermined. ‡ As dextrose. § Amido-acid N 1.22%. ‖ Amido-acid N 0.64%. ¶ As levulose. ** As citric. †† As invert.

Changes in Composition During Development.—Three analyses by Albahary[1] bring out the changes that take place during growth and ripening.

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[1] Compt. rend. 1908, **147**, 146.

COMPOSITION OF GREEN AND RIPE TOMATOES (ALBAHARY)

	Green seed not formed	Green seed formed	Fully ripe
	%	%	%
Water	93.63	94.27	94.39
Volatile matter	0.03	0.12	0.08
Alcohol extract	1.42	3.76	4.48
Fat	0.05	0.08	0.11
Organic acid, fixed	0.12	0.58	0.42
Sugars	0.65	2.07	2.12
Sugars by hydrolysis	0.29	1.14	1.60
Non-protein N	0.02	0.09	0.09
Soluble ash	0.15	0.45	0.38
Dry residue	4.90	1.81	1.08
Acid extract	2.08	0.76	0.89
Protein N	0.29	0.10	0.06
Albumin N	0.18	0.04	0.04
Nuclein N	0.12	0.06	0.02
Sugars as glucoside	0.05	0.09	0.07
Starch	0.07	0.41	0.36
Cellulose	0.75	0.32	0.27
Insoluble ash	0.14	0.14	0.19

Bigelow[1] states that in general the percentage of solids increases as the fruit becomes more mature but the variation in the sugar and acid was so great that no fixed relation could be established. He believes that as a rule the percentage of sugar increases and of acid decreases, at least during the last stages of growth.

Results by Sando[2] show strikingly the changes during development:

COMPOSITION OF TOMATOES AT DIFFERENT STAGES OF DEVELOPMENT

	Days	Water	Protein	N-f. ext.*	Acids †	Sugars, reducing	Sucrose	Starch	Pentosans	Fiber	Ash
		%	%	%	%	%	%	%	%	%	%
Green	14	93.25	1.25	4.37	0.32	1.72	0.02	1.07	0.33	0.50	0.63
Green	21	94.14	0.94	3.90	0.59	1.96	0.04	0.83	0.28	0.46	0.56
Green	28	94.14	0.85	4.03	0.35	2.11	0.00	0.62	0.25	0.45	0.53
Green	35	94.54	0.82	3.65	0.88	2.13	0.02	0.54	0.27	0.48	0.51
Green	42	94.24	0.88	3.95	0.64	2.30	0.07	0.56	0.26	0.43	0.50
Turning	56	94.45	0.77	3.88	0.40	2.54	0.02	0.22	0.23	0.42	0.48
Red	56	94.49	0.73	3.89	0.42	2.64	0.02	0.15	0.24	0.39	0.50

* Includes fat. † As citric.

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[1] Loc. cit.

[2] U. S. Dept. Agr. 1920, Bul. 859.

Influence of Climate on Composition.—Bigelow[1] during two years of experiment was unable to draw definite conclusions. Results obtained by Saywell and Cruess[2] appear to warrant the general conclusion for California tomatoes that the higher the Summer temperature the lower the solids content, but late-harvested fruits contain less solids than early-harvested, and during a drought the solids increase. The locules showed more acid but less solids, reducing sugars, and protein and much less acid hydrolyzable matter than the walls or cores.

Influence of Fertilizers on Composition.—Results by Patterson[3] show no marked difference in composition. In experiments by Bailey and Lodemann[4] the common fertilizing chemicals, applied singly and in combination, produced no marked difference in the composition of the fruit, which ranged as follows: solids 5.86 to 6.04, sugars 4.89 to 5.12, and acid 0.68 to 0.77 per cent; stable manure, however, depressed the solids to 4.92 per cent and the sugars to 3.89 per cent but increased the acid to 0.80 per cent.

The effect of phosphorus on the composition of parts of the tomato plant, including the seed, is the subject of a paper by MacGillivray.[5] Phosphorus starvation greatly reduced the size of the fruit; also, calculated to the dry basis, it decreased the percentage of phosphorus in the fruit but increased the percentage of dry matter and in most cases slightly increased the percentage of total nitrogen and most of the different forms of nitrogen. The decrease in phosphorus content applied to both pulp and seed but chiefly to the pulp; the increase in dry matter, however, was confined to the pulp, the seed showing a decrease.

Influence of Temperature During Storage.—Results of experiments by Haber[6] show that green tomatoes ripen normally and ripe tomatoes keep well at 10° C. (50° F.); after removal from storage both keep well for several weeks. A temperature of 5° C. (40° F.) is too low for ripening during storage and keeping after storage; at 21° C. (70° F.) the fruit rapidly loses moisture, acid, and flavor.

Respiration was found by Gustafson[7] to decrease as the fruit increased in size. When the maximum size was reached, respiration increased up to full coloration, owing it is believed to decrease in hydrogen-ion concentration of the sap, then decreased.

[1] Loc. cit.

[2] California Agr. Exp. Sta. 1932, Bul. **545**.

[3] Loc. cit.

[4] New York Cornell Agr. Exp. Sta. 1891, Bul. **32**, 143.

[5] J. Agr. Res. 1927, **34**, 97.

[6] Iowa State Col. J. Sci. 1931, **5**, 171.

[7] Plant Physiol. 1929, **4**, 349.

Tomato Pulp, consisting of the finely divided fruit flesh of whole tomatoes or trimmings, separated from the skin, seeds, and coarser fibrous material, with or without partial concentration, constitutes an intermediate product in the manufacture of catsup. It is also canned for hotel or domestic use in preparing sauces, soups, etc. The pulping and separation from the seeds, which in the household are laborious, are readily effected in the cannery by the cyclone machine and sieving devices. In the so-called gravity process, used in Italy, the pulped material is allowed to stand until fermentation sets in and the cellular matter rises to the surface. The clear liquid is then removed from below.

Analyses of whole tomato pulp by Bigelow and Fitzgerald[1] show the following range: specific gravity at 20° C. 1.0169 to 1.0465 (in filtrate 1.0158 to 1.0446), total solids 4.34 to 11.21 per cent (in filtrate 3.76 to 10.27 per cent), insoluble solids 0.62 to 1.23 per cent, sugars calculated as invert in filtrate 2.41 to 5.67 per cent, acid calculated as citric in filtrate 0.49 to 0.99 per cent, refraction (immersion) at 17.5° C. of filtrate 32.7 to 56.7, ratio of pulp solids to filtrate solids 1.091 to 1.154, and insoluble solids in total solids 9.8 to 17.4 per cent. Trimmings pulp contained in general somewhat less total solids, sugars, and acid, but more insoluble solids, than whole tomato pulp.

Tomato Catsup, the most popular bottled sauce in the United States, is made in enormous quantities both in the household and in the factory from tomato pulp variously seasoned with spices, vinegar, sugar, salt, onions, garlic, and asafetida.

Winton and Ogden[2] found in commercial catsup a range in solids from 6.03 to 42.64 per cent. Street[3] obtained the following range and average in the examination of 74 commercial brands:

COMPOSITION OF TOMATO CATSUP (STREET)

	Water	Solids, total	Solids, insol.	Protein	Acids*	Fiber	Ash	Salt	Sodium benzoate
	%	%	%	%	%	%	%	%	%
Min....	67.51	7.27	1.23	0.81	0.54	0.32	1.61	0.71	0.00
Max....	92.73	32.49	6.07	3.06	1.98	0.77	6.89	5.17	0.38
Aver...	**83.78**	**6.22**	**2.32**	**1.53**	**1.11**	**0.49**	**3.39**	**2.41**	....

* As acetic.

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[1] J. Ind. Eng. Chem. 1915, 7, 602.

[2] Connecticut Agr. Exp. Sta. Rep. 1901, p. 135.

[3] Ibid. 1910, p. 521.

Seeds and Skins form the residue from the manufacture of tomato pulp. By pressing or extracting the dried residue, with or without the removal of the skins, tomato oil is obtained, the cake serving for feed or fertilizer.

Analyses of the seeds and skin and the seeds by Perciabosco and Semeraro[1] and of the seed cake by Aguet,[2] Rabak,[3] and Rothea[4] follow:

COMPOSITION OF TOMATO RESIDUE (SEEDS AND SKINS), SEEDS, AND SEED CAKE

	Water	Protein	Fat	Lecithin	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%
P. and S.:							
Seeds and skin	6.99	22.81	17.00	0.47	26.69	22.40	4.11
Seeds	8.95	27.62	24.40	0.56	21.41	13.60	4.02
Aguet:							
Seed cake*	10.10	38.13	11.63	....	.....	.....	....
Rabak:							
Seed cake*	7.15	37.00	.....	....	29.10	22.11	4.64
Rothea:							
Seed cake†	8.34	31.23	16.64	....	13.85	23.20	6.74

* Extracted. † Expressed

Proteins.—From ground defatted tomato seeds containing 5.96 per cent of nitrogen, Johns and Gersdorff[5] isolated two globulins, α- and β-, coagulating respectively at 74° and 96° C. on heating 10 minutes, but no albumin or glutelin. The *α-globulin* was precipitated from the 0.5 per cent sodium hydroxide extract on adding ammonium sulphate to 0.3 saturation, the *β-globulin* on complete saturation.

The *Ultimate Composition* was:

	α-Globulin	β-Globulin
	%	%
Carbon	52.29	51.21
Hydrogen	6.89	6.84
Nitrogen	18.34	16.02
Sulphur	1.16	0.81
Oxygen	21.32	25.12

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[1] Staz. sper. agr. ital. 1910, **43**, 260.

[2] Boll. quind. soc. agr. ital. 1913, **18**, 126.

[3] U. S. Dept. Agr. 1917, Bul. **632**.

[4] Bul. sci. pharmacol. 1919, [3], **26**, 105.

[5] J. Biol. Chem. 1922, **51**, 439.

Amino Acids of Tomato Seed Proteins.—Results by Johns and Gersdorff [1] supplemented by figures for tryptophane by Jones, Gersdorff, and Moeller [2] follow:

	α-Globulin	β-Globulin
	%	%
Cystine	1.28	1.14
Tryptophane	1.15	1.45
Arginine	13.97	10.65
Lysine	1.16	3.80
Histidine	4.89	6.35

The *Nitrogen Distribution*, by Van Slyke's method, in tomato seed proteins, was found by Johns and Gersdorff [1] to be as follows:

	α-Globulin	β-Globulin
	%	%
Humin N adsorbed by lime	0.63	1.64
Humin N in ether-amyl alcohol extract	1.58	0.28
Cystine N	0.80	0.83
Arginine N	24.24	21.36
Lysine N	5.05	7.59
Histidine N	1.70	6.43
Amino N of filtrate	53.52	46.47
Non-amino N of filtrate	1.73	4.46
Amide N	11.60	11.69
	100.85	100.75

Alkaloids.—Laland[3] found *narcotine* in unripe tomatoes; at later stages this passes into vitamin C.

Fatty Oil of Seed.—Tomato seeds, obtained as a by-product in the preparation of tomato pulp, are rich in oil, the composition and utilization of which have been studied by Perciabosco and Semeraro,[4] Aguet,[5] Rabak,[6] Rothea,[7] Jamieson and Bailey,[8] and others.

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[1] Loc. cit.

[2] Ibid. 1924, **62**, 183.

[3] Z. physiol. Chem. 1932, **204**, 112.

[4] Loc. cit.

[5] Loc. cit.

[6] Loc. cit.

[7] Loc. cit.

[8] J. Ind. Eng. Chem. 1919, **11**, 850.

Physical and Chemical Values.—Of the figures in the following ble those reported by Perciabosco and Semeraro and by Rabak are n the extracted oil, in the former case without separation from the kins, while those by Rothea and by Jamieson and Bailey are mostly n the expressed oil, which in some instances, however, was refined or leached:

VALUES OF TOMATO SEED OIL

	Sp. gr. 15° C.	Ref. index 25° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Hehner No.	Acetyl No.	Acid No.
. and S..	0.9244	....	189.0	87.7	0.2	...	....	....	1.8
abak:									
Crude..	0.9278	1.4694	190.4	108.0	...	...	....	....	8.8
Refined.	0.9242	1.4715	188.6	114.2	...	...	....	....	2.5
othea...	0.9216	1.4745*	195.4	115.0	...	...	....	....	6.9
. and B. .									
Min....	0.9248	1.4715	187.0	117.5	0.1	0.4	95.0	10.0	...
Max....	0.9260	1.4728	192.0	125.0	0.3	0.6	96.6	20.5	...

* Temperature not stated.

Composition.—Rabak showed that his refined oil contained 17.54 per cent of solid acids and 75.84 per cent of liquid acids and that its approximate composition was:

	%
Glycerides of:	
Stearic acid....................	5.89
Palmitic acid....................	12.47
Oleic acid.....................	45.00
Linolic acid....................	34.20
Free acids and unsaponifiable matter	2.44
	100.00

Jamieson and Bailey found in their samples 14.7 to 18.0 per cent of saturated (solid) acids and 76.1 to 80.6 per cent of unsaturated (liquid) acids, also *arachidic acid* present to the extent of at least 0.4 per cent.

Acids.—The earlier chemists considered that *malic acid* was the sole acid of the tomato, but Stüber,[1] also Formenti and Scipiotti,[2] found that it was largely if not entirely *citric acid.* Albahary[1] found i a sample, containing 93.5 per cent of water, free acids as follows: mali 0.48, citric 0.09, and *oxalic* 0.001 per cent, and *tartaric* and *succin* traces.

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[1] Z. Unters. Nahr.-Genussm. 1906, 11, 578.

[2] Ibid. 1906, 12, 283.

Bacon and Dunbar[2] state that tomatoes contain on the averag about 6.4 per cent of solids consisting of 0.9 per cent of protein, 0.0 per cent of fat, 3.5 per cent of invert sugar, 0.5 per cent of citric acic 0.85 per cent of fiber, and 0.6 per cent of ash. In ripe tomatoes the obtained negative tests for malic and oxalic acids by methods accurat respectively to 0.02 and 0.01 per cent. On spoilage, *lactic* and *aceti acids* are formed from the sugars as shown by the following figures:

Composition of Fresh and Spoiled Tomatoes (Bacon and Dunbar)

	Solids	Reducing sugars as invert	Total acids as citric	Citric acid	Volatile acids as acetic	Lactic acid	Polarization
	%	%	%	%	%	%	°V
I							
Fresh	....	...	0.56	0.58	0.000	0.00	—4.0
Room temp. 2 weeks	....	...	0.60	0.00	0.462	0.37	0.0
II							
Fresh	5.80	3.3	0.60	....	0.00	0.00	—6.15
Warm place 10 days	3.66	0.0	0.59	....	0.12	0.48	0.00

Kremers and Hall,[3] who state that Hansen (unpublished results) was the first to isolate citric acid in crystal form from tomato juice, demonstrated the presence of this acid by successive preparation of crude calcium citrate and the triphenacyl ester, the latter melting at 104 to 105° C. Duggar and Merrill[4] suggest the possible retarding influence of the acid of the tomato on the formation of the pigment. Fruits of the same variety grown under the same conditions were remarkably uniform in their citric acid content throughout ripening.

Yoshimura and Nishida[5] isolated 4.45 grams of malic acid and 4.70 grams of citric acid from the hot water extract of 100 kilos of tomatoes. Bornträger[6] notes that in some samples malic, in others citric acid is in xcess, also that in soft, but still edible, fruit succinic acid is present. The citric acid of the ripe fruit exists as primary citrates, never as a ieutral salt, with smaller amounts of secondary citrates, while malic acid exists chiefly as an acid malate. The presence of secondary citrates explains the mild taste of some tomatoes. The free acid as malic never exceeds 0.05 per cent. Phosphates increase on ripening. Although a trace of oxalic acid may occur in very green or spoiled canned tomatoes, none is present in the ripe fruit. During softening, citric and malic acids disappear. Over-ripe fruit may contain *arabic acid.* Glycolic acid does not occur in sound ripe fruit.

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[1] Loc. cit.

[2] U. S. Dept. Agr., Bur. Chem. 1911, Circ. **78**.

[3] J. Biol. Chem. 1920, **41**, 15.

[4] Ann. Missouri Bot. Gard. 1914, **1**, 237.

[5] J. Chem. Soc. Japan, 1924, **45**, 57.

[6] Z. Unters. Nahr.-Genussm. 1925, **50**, 273; 1928, **55**, 112; 1932, **63**, 447.

Pectins.—Bornträger[1] found only traces of pectin in ripe tomato juice and none in the juice of green or over-ripe fruit; however, by heating on a water-bath tomatoes in various stages of ripening, except over-ripe, he dissolved a large amount of pectin.

Analyses by Appleman and Conrad[2] of green, pink, and red-ripe tomatoes show respectively: protopectin 2.37, 2.18, and 1.58, pectin 1.06, 2.47, and 3.05 per cent, dry basis, hence there is a progressive change from protopectin to pectin. During processing there is a further change which is especially marked on slow cooling. Following are the average results on protopectin and pectin of tests extending from August 16 to September 21: Bonney Best, rapid cooled, 0.64, 2.75, slow cooled, 0.42, 2.98; Greater Baltimore, rapid cooled, 0.70, 2.58, slow cooled, 0.40, 2.97; Stone, rapid cooled, 0.66, 2.49, slow cooled, 0.41, 3.02; Marglobe, rapid cooled, 0.57, 2.31, slow cooled, 0.30, 2.51 per cent, dry basis.

Le Crone and Haber[3] note that the rate of increase in soluble pectin during ripening on the vine and in storage is directly proportional to the temperature, but during prolonged storage, as well as during softening, both soluble and insoluble pectin decrease. Softening is accompanied by a change from insoluble to soluble pectin.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[4] reports about 6.68 per cent, dry basis.

Colors.—The carotenoids of the tomato, *carotene* and *lycopene*, are described in the Introduction to this volume and under Microscopic Structure above.

The pigments in Italian- and American-grown red and in American-grown purple tomatoes have been shown by Matlack and Sando[5] to be identical.

[1] Z. Unters. Lebensm. 1928, **55**, 112.

[2] Maryland Agr. Exp. Sta. 1928, Bul. **291**.

[3] Iowa State Col. J. Sci. 1933, **7**, 467.

[4] Philippine Agr. 1932, **21**, 53.

[5] J. Biol. Chem. 1934, **104**, 407.

Enzymes.—Studies by Haber[1] show that *oxidase* is more active in ripe than in green fruit, and *catalase* is less active.

Mineral Constituents.—An analysis by Passerini[2] of the pure ash of the fresh fruit and by Perciabosco and Semeraro[3] of the ash of the dried seeds and skins and of the dried seeds obtained in the manufacture of tomato pulp follow:

Composition of Tomato Ash

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	Cl	SiO_2
	%	%	%	%	%	%	%	%	%
Fruit..........	59.46	5.99	1.34	3.09	0.22	12.93	3.49	19.14	0.27
Seeds and skins.	18.98	1.33	7.11	8.59	6.93*	24.77	....	....	....
Seeds..........	13.50	0.75	29.32	4.26	8.25*	41.04	....	....	....

* Includes Al_2O_3.

Minor Mineral Constituents. *Iron.*—Fruit 6 mg. per kilo, fresh basis (Peterson and Elvehjem).[4] Fruit, 2 samples, 3.6, 4.9 mg. per kilo, fresh basis (Toscani and Reznikoff).[5] Fruit, peeled 4 mg. per kilo, fresh basis (Sherman).[6] Fruit, whole, 8 samples, 115 to 185, aver. **148** mg. per kilo, dry basis (Remington and Shiver).[7] Brautlecht and Crawford[8] found unusually large amounts in tomatoes canned in Florida.

Aluminum.—Fruit 23 mg. per kilo, dry basis (Bertrand and Lévy).[9]

Manganese.—Fruit, whole, 8 samples, 17.7 to 33.7, aver. **25.7** mg. per kilo, dry basis (Remington and Shiver).[7] Fruit, fresh basis 0.62, dry basis 12.6 mg. per kilo (McHargue).[10] Fruit 24 mg. per kilo, dry basis (Peterson and Skinner).[11]

Copper.—Juice and pulp, fresh basis 0.14 to 2.10, dry basis 3.8 to 19.5 mg. per kilo (Marsiglia and Zay).[12] Fruit, 2.0 mg. per kilo, fresh basis (Guérithault).[13] Fruit, 8 samples, 7.7 to 33.8, aver. **17.4** mg. per kilo, dry basis (Remington and Shiver).[7] Fruit 0.6 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[14]

Zinc.—Fruit 2.4 mg. per kilo, fresh basis (Bertrand and Benzon).[15]

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[1] Iowa State Col. J. Sci. 1928, **3**, 29.

[2] Loc. cit.

[3] Loc. cit.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Nutrition 1934, **7**, 79.

[6] U. S. Dept., Off. Exp. Sta. 1907, Bul. **185**.

[7] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[8] J. Ind. Eng. Chem. 1914, **6**, 1001.

[9] Compt. rend. 1931, **192**, 525.

[10] J. Agr. Res. 1924, **27**, 417.

[11] J. Nutrition 1931, **4**, 419.

[12] Ann. staz. chim. agr. sper. Roma 1916, [2], **8**, 163.

[13] Bul. soc. hyg. aliment. 1927, **15**, 386.

[14] J. Biol. Chem. 1929, **82**, 465.

[15] Bul. soc. hyg. aliment. 1928, **16**, 457.

EGG PLANT

Solanum Melongena L. = *S. esculentum* Dunal

Fr. Augerbine. Sp. Berergena. It. Melanzana. Ger. Eierkartoffel.

Although tropical America is particularly rich in species of the genus *Solanum*, western Asia claims the egg plant. Common egg plant (var. *esculentum* Nees), of which there are purple- and white-fruited varieties, and dwarf purple egg plant (var. *depressum* Bailey) have egg-shaped fruit; snake egg plant (var. *serpentinum* Bailey) has elongated sausage-shaped fruit popular with Chinese residents of the United States.

MACROSCOPIC STRUCTURE (Fig. 124).—The *flower* of the common egg plant is somewhat flattened and has three or four placentæ each side of the ovary. Later, by crowding of the pericarp tissues, the cavities about the seeds become entirely filled with a white mass of uniform structure.

The *calyx*, which persists on the fruit, is coarse, thick, prickly, and densely hairy with five or more pointed lobes. The *fruit* of common and dwarf varieties is flattened egg-shaped, while that of the snake variety is narrow, much elongated, and somewhat curved. All varieties regardless of form and color (purple, white, etc.) have a lustrous skin more or less scarred at the apex. Tufted hairs clothe the surface when immature, but many of them disappear at maturity.

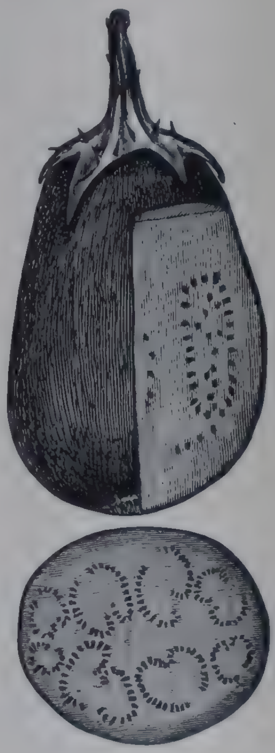

Fig. 124. — Egg Plant. Fruit in longitudinal and cross section showing seeds embedded in colorless tissue. × 1/5. (K.B.W.)

The *seeds* are flattened kidney-shaped, 3 to 4 mm. in diameter, resembling closely those of paprika and other varieties of *Capsicum annuum* but are brownish in color—at least in purple varieties. Embedded in the bulky endosperm is the curved embryo, the elongated cotyledons of which are several times as long as the radicle.

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* (Fig. 126) of small, irregularly thickened, beaded cells interspersed with tufted hairs (Fig. 125) on slight elevations; (2) *hypoderm* also of beaded cells, about three thick; (3) *mesocarp* (Fig. 127, *mes*), of loose parenchyma cells increasing in size inward until quite spongy, containing chlorophyl grains in the outer cells and small starch grains in the vicinity of the ramifying fibro-vascular bundles; and (4) *endocarp* of delicate, irregular cells.

Both the epicarp and hypoderm of purple varieties contain the colo in solution. The conspicuous elements of the *fibro-vascular bundle* (Fig. 127) are large sieve tubes (*s*) and spiral (*sp*), reticulated (*ret*) and pitted vessels (*g*).

Spermoderm (Fig. 128, *S*; Fig. 129).—Mature seeds in cross section show (1) *outer epiderm* (*aep*) with curiously thickened and sclerenchymatized walls, (2) compressed *parenchyma* (*p*), and (3) *inner epiderm* (*iep*) of which only the cuticle is evident at maturity.

As in paprika, between the thin cuticle (*cut*) and the thin sclerenchymatized inner lamella (*scl*) of the outer wall of the *outer epiderm* there is a thick lamella of cellulose (*c*). The sclerenchymatized radial walls show small cavities at the outer ends. In surface view (Fig. 129) the cells are somewhat elongated with compoundly sinuous, thickened walls and show on careful focusing large pores in the sclerenchymatized inner wall and a beaded middle lamella due to the cavities seen in cross section.

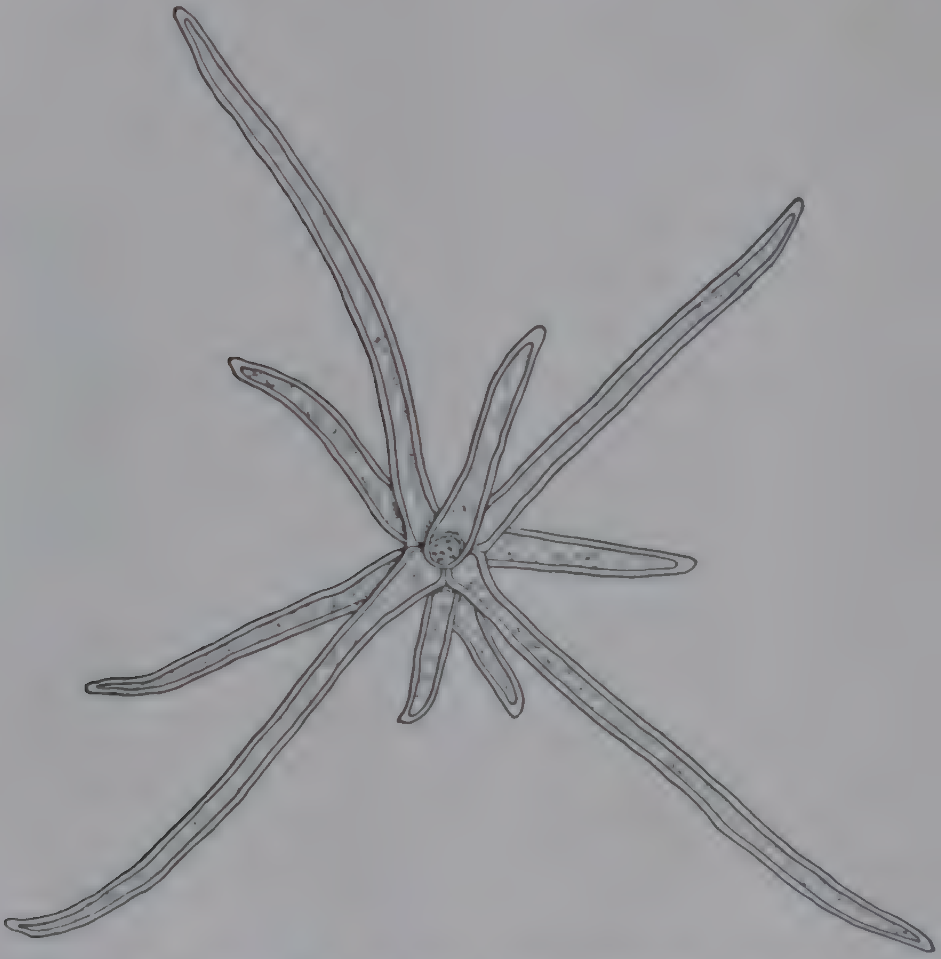

Fig. 125.—Egg Plant. Tufted hair from pericarp. × 160. (K.B.W.)

Endosperm (Fig. 128, *E*).—Throughout, this consists of small moderately thick-walled cells with small aleurone grains (*al*).

Embryo.—The tissues are delicate and characterless.

Chief Structural Characters.—Fruit smooth, egg- or sausage-shaped, purple or white, solid (no cavities); placentæ commonly more than two; seeds numerous.

Epicarp of beaded cells and tufted hairs; hypoderm beaded; mesocarp spongy. Outer epiderm of spermoderm with sclerenchymatized, much-thickened, porous side walls and thin sclerenchymatized lamella of outer wall within a thicker cellulose lamella. Endosperm and embryo containing small aleurone grains.

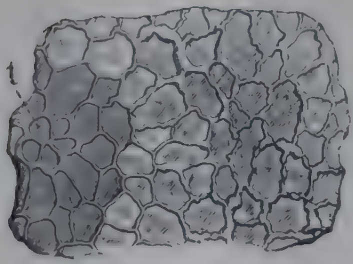

Fig. 126.

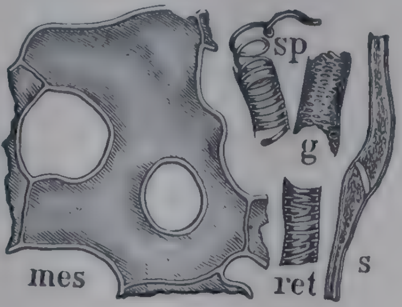

Fig. 127.

Fig. 126.—Egg Plant. Epicarp in surface view; *t* hair scar. ×160. (K.B.W.)

Fig. 127.—Egg Plant. Elements of fruit flesh. *mes* cell from spongy mesocarp; *sp* spiral, *g* pitted, and *ret* reticulated vessels; *s* sieve tube. ×160. (K.B.W.)

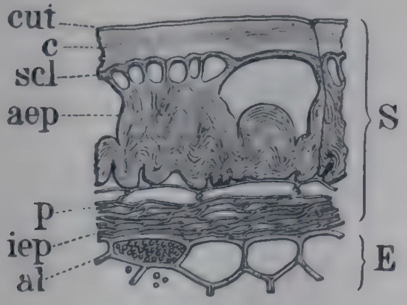

Fig. 128.

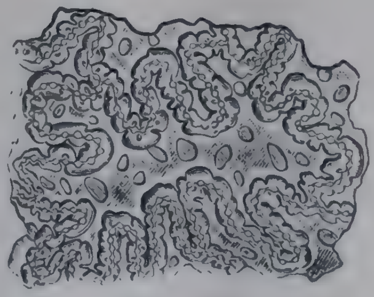

Fig. 129.

Fig. 128.—Egg Plant. Outer portion of seed from flat side in cross section. *S* spermoderm: *aep* outer epiderm with *cut* cuticle, *c* cellulose lamella, and *scl* sclerenchymatized lamella; *p* compressed parenchyma; *iep* cuticularized remains of inner epiderm. *E* endosperm of *al* aleurone cells. × 160. (K.B.W.)

Fig. 129.—Egg Plant. Outer epiderm of spermoderm in surface view showing beads due to cavities shown in Fig. 128. × 160. (K.B.W.)

CHEMICAL COMPOSITION.—The composition of the common large purple fruit is illustrated by analyses reported by Zega[1] and by Atwater and Bryant,[2] the samples having been grown in Serbia and the United States respectively. Analyses of the white snake fruit are given by Blasdale,[1] Agcaoili,[2] Adolph,[3] and Chung and Ripperton.[4] Blasdale's sample was sold in the Chinese Quarter of San Francisco under the name of *pak ke*; Adolph's sample was grown in the vicinity of the Chinese Christian College at Sinanfu, China, where it is known as *ch'ieh-tzu*; and Chung and Ripperton's sample represents the Hawaiian product known by the Chinese as *ai-kwa* and by the Japanese as *nanbu-naga nasu*. Agcaoili gives *talong* as the common name in the Philippines.

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[1] Chem. Ztg. 1898, **22**, 975.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

COMPOSITION OF EGG PLANT

	Water	Protein	Protein, pure	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Common:										
Zega....	92.27	1.51	....	0.08	4.52	....	....	....	0.89	0.70
A. and B.	92.90	1.2	0.6	0.3	4.30	....	....	....	0.8	0.5
Chinese:										
Blasdale.	89.62	1.38	1.08	0.30	6.47	1.31	0.63	1.57	1.54	0.69
Agcaoili.	90.98	1.07	....	0.45	6.14	....	....	....	0.82	0.54
Adolph..	93.26	2.31	....	0.07	3.05	....	....	....	0.77	0.54
C. and R.	93.37	1.14	....	0.05	4.05	....	....	....	0.85	0.54

König[5] quotes analyses by Kellner and by Nagai and Murai of the vegetable grown in Japan and an analysis by Greshoff, Sack, and Van Eck of a sample from India.

Analyses made by Culpepper and Moon[6] show that the soluble and insoluble solids of egg plant increase in considerable amount only in the early stages of growth. The solids, sugars, starch, and nitrogen remain nearly constant during the later periods. The range in composition of the fruit of 10 varieties 50 to 70 days after setting follows:

	Solids, sol.	Solids, insol.	Protein	Acids	Sugars, reducing	Sucrose	Starch†	Astringency	Nitrogen	
									Total	Nitrate
	%	%	%	%	%	%	%	%	%	%
Min..	3.00	2.99	0.73*	0.130	1.17	0.28	0.78	0.079	0.117*	0.00017
Max..	4.88	5.25	1.16*	0.299	2.86	1.09	1.31	0.215	0.186*	0.00227

* 2 samples. † Hydrolyzable substances.

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[1] U.S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] Ibid. 1926, **30**, 287.

[4] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[5] Chem. mensch. Nahr.-Genussm., Berlin, 1903, **1**, 738, 1498.

[6] J. Agr. Res. 1933, **47**, 705.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[1] reports about 2.04 per cent, dry basis.

Mineral Constituents.—Chung and Ripperton[2] found: calcium 0.010, iron 0.0017, and phosphorus 0.034 per cent; also alkalinity of ash 6.30 expressed as cubic centimeters of normal acid per 100 grams fresh vegetable.

Minor Mineral Constituents. *Iron.*—Fruit 6.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Manganese.—Fruit, 3 samples, 19.7 to 39.2, aver. **31.1** mg. per kilo, dry basis (Remington and Shiver).[4] Fruit 14.6 mg. per kilo, dry basis (Peterson and Skinner).[5]

Copper.—Fruit, 3 samples, 10.5 to 15.7, aver. **12.7** mg. per kilo, dry basis (Remington and Shiver).[4] Fruit 1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Fruit 2.8 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

GARDEN PEPPERS

Capsicum spp.

Peppers grown in the vegetable garden for the most part are varieties of *C. annuum* L. They are classed as sweet or mild and hot or pungent. This classification is independent of the form of fruit which varies from long and narrow to short and thick, the latter being the usual form used green or ripe and in the latter case fresh or dried. Varieties that yield paprika and capsicum may also be grown as garden peppers and on the other hand the fruit of any garden variety may be dried for winter use. (See Paprika, Vol. III).

CHEMICAL COMPOSITION.—Analyses by Zega[8] of green peppers with both long and broad pods containing little or no capsaicin, much used as a vegetable in Serbia, show the limits given in the following table:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Min.	85.61	1.02	0.34	4.01	1.02	0.50
Max.	91.50	2.25	4.00	7.52	2.84	1.16

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[1] Philippine Agr. 1932, **21**, 53.

[2] Loc. cit.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Ass. Off. Agr. Chem. 1930, **13**, 129.

[5] J. Nutrition 1931, **4**, 419.

[6] J. Biol. Chem. 1929, **82**, 465.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

[8] Chem. Ztg. 1911, **35**, 51.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[1] reports 1.98 per cent, dry basis.

Colors.—Zechmeister and Von Cholnoky[2] describe the carotenoids they have separated from paprika and identified. Of these, *capsanthin* is characteristic. From 1 kilo of dry paprika, Von Cholnoky[3] by adsorption methods obtained capsanthin 1.3, xanthophyl (lutein + zeaxanthin, both $C_{40}H_{56}O_2$) 0.6, and carotene 1.3 grams. See Capsanthin in introduction to this volume.

Minor Mineral Constituents. *Iron.*—Peppers, green 4.1, red 6.0 mg. per kilo, fresh basis (Peterson and Elvehjem).[4] Green, 2 samples, 4.0, 10.5 mg. per kilo, fresh basis (Toscani and Reznikoff).[5]

Manganese.—Green peppers 19.1 mg. per kilo, dry basis (Peterson and Skinner).[6]

Copper.—Green peppers 1.0 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

STRAWBERRY TOMATO

Physalis pubescens L.

Fr. Physalide. Ger. Capische Stachelbeere.

Other names are husk tomato and Winter cherry, the latter name referring to the remarkable keeping qualities of the fruit when stored in the husk. It has also been called the dwarf Cape gooseberry, the true Cape gooseberry being *P. peruviana L.* The delicious fruit is little known and grown in the United States where it is native.

MACROSCOPIC STRUCTURE.—Compared with the true Cape gooseberry the plant is more procumbent. Stem, petioles, leaves (toothed or entire), and calyx are hairy and more or less ribbed or veined with red. When in flower the *calyx* is globular, about 2 mm. long, not including the lobes which are about 3 mm. long. The bell-shaped, five-toothed *corolla* reaches 1 cm. or more in diameter at the top and is straw-colored with five purplish brown spots. After the corolla falls the calyx further develops, the tube reaching a maximum of 2.5 cm. and forming a loose, five-angled bladder-like covering about the fruit. It then changes from green to light buff, and the glossy, globular *fruit* which has reached a maximum of 1.5 cm. changes from green to yellow.

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[1] Philippine Agr. 1932, **21**, 53.

[2] Ann. 1927, **454**, 54; 1927, **455**, 70; 1928, **465**, 288; 1930, **478**, 95; 1931, **487**, 197.

[3] Magyar Gyógyserésrud. Társasag Értesitöje 1933, **9**, 400; Chem. Abs. 1934, **28**, 2031.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Nutrition 1934, **7**, 79.

[6] Ibid. 1931, **4**, 419.

[7] J. Biol. Chem. 1929, **82**, 465.

After calyx and fruit drop the fruit further ripens, becoming bright yellow and developing its aroma. It will keep nearly all winter. The husked fruit is two-celled and contains numerous *seeds* 1.5 mm. long, with a leathery spermoderm, a bulky endosperm, and a curved embryo.

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* with polygonal, beaded cells somewhat larger (maximum 100 μ) than those of the tomato, (2) *hypoderm* of still larger cells with wavy walls, (3) *mesocarp* of characterless parenchyma and delicate fibro-vascular bundles, and (4) *endocarp* of inconspicuous thin-walled cells.

Spermoderm.—Only the *outer epiderm* (Fig. 130) is noticeable, the cells of the remaining layers being collapsed. The radial walls are thickened and sclerenchymatized to such an extent as nearly to obliterate the lumen; otherwise they are quite simple in structure, being without sharp sinuosities (present in tomato, egg plant, paprika, garden peppers, and cayenne). Cross sections show that the outer wall is of cellulose and thin as in the tomato, while the inner wall has large folds (present in egg plant) but no warts (present in paprika and garden peppers), or pores (present in egg plant).

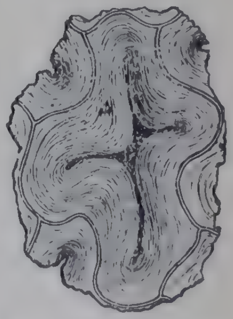

FIG. 130.—Strawberry Tomato. Epiderm of spermoderm in surface view. × 160. (K.B.W.)

The **Endosperm** with rigid walls and the **Embryo** with thin walls, both containing small aleurone grains, are much the same as in the tomato.

CHIEF STRUCTURAL CHARACTERS. — Fruit small, two-celled, yellow, enveloped in papery calyx; seeds numerous, flattened, 1.5 mm. in diameter.

Epicarp cells beaded, somewhat larger than in tomato; remainder of pericarp characterless. Outer epidermal cells of spermoderm with thickened radial and inner walls, nearly closing the lumen, but with thin outer wall; sharp sinuosities, warts, and pores absent.

CHEMICAL COMPOSITION.—No data on the strawberry tomato are available but an analysis of the closely related Cape gooseberry (*P. peruviana* L.) was made at the Government Laboratory at Durban by King[1] and 2 analyses were made by Thompson[2] of the fruit grown in Hawaii, where it is known as *poha*.

Acids.—King states that in his sample the acid consisted chiefly of *citric* but *malic* and *tartaric* were also present and that 54 per cent of the ash consisted of potash. Animal experiments by Caserio[3] indicate

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[1] Chem. News. 1910, **102**, 320.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[3] Z. Vitaminforsch. 1934, **3**, 93.

Composition of Cape Gooseberry

	Water	Solids, insol.	Protein	Fat	Acids as citric	Sugars, total	Invert sugar	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Africa...	82.61	....	2.68	1.23	1.69	9.59	3.13	6.46	2.04	0.82
Hawaii:										
I.....	82.14	6.78	....	0.33	2.11	8.64	2.67	5.97	4.73	0.73
II.....	82.24	7.09	2.01	0.30	1.78	7.74	2.25	5.49	3.82	0.83

that the juice of the Winter cherry (*P. alkekengi*) is twice as rich in vitamin C and presumably *ascorbic acid* as lemon juice.

Colors.—See Physaliene under Introduction to this volume.

BLACK NIGHTSHADE

Solanum nigrum L.

Fr. Morelle noire. Sp. Solano. It. Solano. Ger. Nachtschatten.

The black nightshade is a native of Europe, Asia, and America. Although it has long been considered a dangerous plant because of its alleged solanin content, the creoles of the West Indies gather the leaves for greens, and in the Middle West, where it is known as "stubble berry" because of its occurrence in wheat stubble, the sweet, rather insipid fruit is used for pies and jams.

The variety *guineense* L. is sparingly cultivated as "the garden huckleberry."

MACROSCOPIC STRUCTURE.—The *fruit*, borne in small, loose clusters, is round, dull blue-black in color, about 7 mm. in diameter, with numerous flattened *seeds* about 1.5 mm. in length.

MICROSCOPIC STRUCTURE. Pericarp.—The tissues consist of delicate rounded pulp cells with an *epicarp* of strongly beaded, polygonal, sometimes quadrilateral or slightly wavy-walled cells, up to about 80 μ in diameter with striated cuticle. The purple color is in solution in the outer tissues.

Spermoderm.—The *outer epiderm*, as seen in cross section, has in the inner half curiously thickened and sinuous walls, similar to those of the garden peppers, and in the outer half thin radial walls with delicate rod-like radial thickenings.

The coat is about 50 μ thick on the flat side of the seed, becoming considerably thicker over the edge.

Endosperm and **Embryo.**—Practically as in related sepcies.

CHEMICAL COMPOSITION.—Valenzuala and Wester[1] report a ingle analysis as follows:

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
86.02	2.51	0.56	5.57	4.15	1.19

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[1] Philippine J. Sci. 1930, **41**, 85.

FRUITS OF THE MARTYNIA FAMILY

(*Martyniaceæ*)

Only one species, the proboscis flower, is here described. Creole scorzonera (*Craniolaria annua* L. = *Martynia Craniolaria* Glox.), a species of an allied genus, yields fleshy roots which in South America are eaten as a vegetable or as a sweetmeat. It should not be confused with the composite root vegetable scorzonera.

UNICORN PLANT

Martynia louisiana Mill. = *M. proboscidea* Glox.
= *Proboscidea Jussieui* Steud.

Fr. Cornes de diable. It. Testa di quaglia. Ger. Elephantenrüssel.

This plant as well as other members of the genus is a native of sub-tropical America. It is grown in the vegetable garden for the immature pods which are pickled like cucumbers.

MACROSCOPIC STRUCTURE.—Throughout, the plant is clothed with clammy hairs. Both the thick *stem* (often 3 cm.) and the petioles (often 1 cm.) are hollow, streaked with red. The *leaves* are heart-shaped. The gloxinia-like *flowers* have an irregularly five-lobed white or purplish calyx and an oblique corolla. The lobes of the corolla vary from light pink to deep rose; the throat is nearly colorless, variously spotted with crimson.

The one-celled *ovary* has two parietal placentæ which are bifurcated, thus forming in the fruit (Fig. 131, II) four outer false cells and one central cell. At the edible stage the *fruit* (Fig. 131, I) and its curved horn are 4 to 6 cm. long, densely clothed with glandular hairs, up to more than 3 mm. long, arising from a bright green epicarp. In cross section it is green to the depth of about 1 mm., then white, and finally glassy about the numerous seeds, which at this stage are white. On further growth the *pod* becomes tough and the fleshy part splits and drops away as two valves, each with a long (6 to 8 cm.) claw, while the woody endocarp, without separating from its peduncle, likewise splits into two halves, each also with a long claw, thus releasing the seeds. Each half of the endocarp bears on the inner edge, extending the base of the claw, a row of irregular spines which together with ne sharp claw are a menace to unprotected ankles.

The *seeds* are somewhat elongated, up to 1 cm. long. The spermoderm is leathery, 1 to 2 mm. thick, rough on the outer surface and ead black throughout, contrasting strongly with the thin endosperm nd fleshy cotyledons which are pure white.

MICROSCOPIC STRUCTURE. Pericarp.—The remarkable *hairs* Fig. 131, III), arising from among the beaded cells and stomata of he *epicarp*, are the chief objects of interest. These were noted by Martinet,[1] and his cut was used by Goodale [2] to illustrate the glandular ype of hair. They are jointed with a head which in the earlier stages s globular but later becomes urn-shaped. The head is formed by a ircle of wedge-shaped—that is elongated oth parallel with and at right angles to the axis—cells about four central cells. The secretion collects beneath the cuticle and finally exudes when the cuticle has been distended to the breaking point. According to Hanstein,[3] a new cuticle then forms, within which a new drop of secretion collects. When the hair ceases to function the head turns brown. The joints of the hair immediately below the head contain numerous chlorophyl grains.

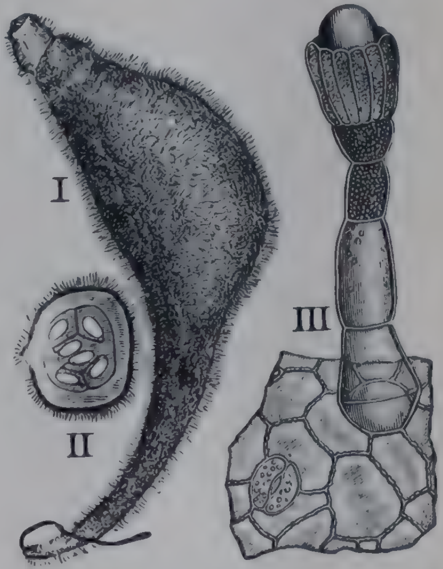

Fig. 131.—Unicorn Plant. I and II pod, pickling size. × 1. (A.L.W.) III Epicarp with secretion hair. × 160. (K.B.W.)

At maturity, as well as in the earlier stages, the *mesocarp* is characterless. Chlorophyl grains in the outer layers are the visible contents.

The *endocarp*, which at the edible stage is of soft tissue, finally becomes hard and woody. Cross sections show that it is made up of a stockade of cylindrical bast fiber bundles, each wrapped about with and separated from its neighbor by numerous fibers similar to the insulation of an electric wire. This formation resembles that in the pericarp of the species of *Ambrosia* (see Kinghead, Vol. I) but is more striking.

Spermoderm.—Cross sections of the mature black seed show that the cells are large (up to 200 μ), with thick gray-yellow walls (up to 40 μ) and broad lumens.

Embryo.—The cotyledons are of typical structure with *palisade cells* beneath the *inner epiderm.* Aleurone grains and fat are the visible contents.

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[1] Ann. sci. nat. 1872, **14**, 91.

[2] Physiol. Botany, New York, 1885, p. 68.

[3] De Bary: Comp. Anat. Phan. Ferns, Oxford, 1884, p. 89.

Chief Structural Characters.—Fruit beaked, glandular, hairy. Seed black with leathery spermoderm, thin endosperm, and fleshy cotyledons.

Hairs jointed, glandular, with multicellular heads; endocarp of fiber bundles wrapped with numerous fibers. Spermoderm of large cells with thick walls.

CHEMICAL COMPOSITION.—An analysis of the immature fruit used for pickling is not available.

The mature *seeds*, as analyzed by Bailey and Long,[1] contain: water 2.91, protein 24.41, fat 60.63, starch 4.55, fiber 3.05, and ash 3.80 per cent.

Fatty Oil of Seed.—Two samples [1] of the hot-pressed oil show the following values: specific gravity at 15.5° C. 0.9157, refractive index at 25° C. (recalculated) 1.4725 and 1.4732, saponification number 197.1 and 198.6, and iodine number 122.3 and 122.8.

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[1] J. Ind. Eng. Chem. 1915, **7**, 867.

FRUITS OF THE GOURD FAMILY

(*Cucurbitaceæ*)

OF THE four tribes, two include all the species grown in the temperate zone as follows:

I. *Cucurbitæ.—Cucurbita* (pumpkin, squash), *Cucumis* (cucumber, muskmelon), *Citrullus* (watermelon), *Sicana* (cassabanana), *Momordica* (balsam pear, balsam apple), *Luffa* (dish-cloth gourd), *Benincasa* (wax gourd).
II. *Sicyoidæ.—Sechium* (chayote).

Mention should also be made of *Telfairia pedata* Hook. (*Cucurbitæ*), East Africa, with an enormous fruit and numerous seeds used for food and oil production, and *Acanthosicyos horrida* Welw. (*Sicyoidæ*), the fruit of which is eaten by the Hottentots.

COMPARATIVE MACROSCOPIC STRUCTURE. Flower.—The flowers are usually monœcious. Both the calyx and the more or less lobed corolla are superior, being united with the ovary or, according to some botanists, with the receptacle. In most of the species the ovary is three-celled and many-seeded but in the chayote it is one-celled and one-seeded.

The **Fruit** is of various well known shapes. At maturity it is hollow, solid, or fibrous. In the balsam pear it dehisces, exposing the seeds enclosed in scarlet inner fruit flesh. The ovary protrudes from the receptacle in the turban squash. Longitudinal grooves occur on the pumpkin and muskmelon, warts on the squash and balsam pear, and spines on the cucumber and some varieties of chayote.

Hairs are present during the early stages of growth, but on ripening persist only in the grooves or between warts. *Cork* forms a network on the muskmelon, but is absent on the cassaba melon which is a variety of the same species. The *fruit-flesh* is either uniform in color, usually orange or yellow, or else is white in the rind and red or yellow in the inner fruit flesh (watermelon).

Seed.—In the *Cucurbitæ* the seeds are borne on central placentæ extending to the outer wall where they divide and turn back simulating parietal placentæ. The single seed of *Sechium* is suspended in the cavity.

All the species here described have anatropous, flattened, more or less pointed elliptical seeds, each with leathery spermoderm, thin endosperm, and bulky embryo consisting of large cotyledons and short straight radicle. Seeds of the pumpkin group have a plain raised margin and of the balsam pear a scalloped margin.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—The four layers of the pericarp are (1) *epicarp* of rounded polygonal, more or less thick-walled and radially elongated cells, stomata with thin walls, and, in the early stages, jointed and capitate hairs; (2) *hypoderm*, many cells thick, of small-celled parenchyma except in the cucumber which has occasional sclerenchyma cells under the emergences and in the chayote where it consists largely of fibers; (3) *mesocarp* more or less differentiated into three zones, the outer usually rich in stone cells, the middle and inner of parenchyma cells often containing starch or oxalate crystals, through which run anastomosing bicollateral vascular bundles, isolated sieve tubes, and latex tubes; and (4) *endocarp* of thin-walled, more or less tangentially elongated cells often adhering to the seed. The parenchyma cells are large in the middle zone, diminishing in size in the inner zone. They contain starch (pumpkin, cassabanana, chayote), crystals (balsam pear), or no evident contents.

Bræmer[1] and later authors do not accept the view of Fischer[2] that what appear to be latex tubes are isolated sieve tubes that have ceased to function, as the lack of sieve plates and the presence of granular milky contents which harden in alcohol seem abundant proof that they are true latex tubes.

Spermoderm.—All of the tissues are quite uniform over the flat side of the seed but vary at the edges.

The five layers of the *Cucurbitæ* tribe are (1) *outer epiderm* of prismatic palisade cells, polygonal in surface view, and, except for a few cases, with peculiar thickenings on the radial walls; (2) *subepiderm* of one of more layers of cells varying greatly in size and shape and in wall thickness; (3) *sclerenchyma layer* of cells with exceedingly thick sinuous walls, isodiametric or elongated longitudinally or radially, with remarkable dovetailed branches; (4) *parenchyma layer* of close or spongy tissue which in the pumpkin, squash, and balsam pear is differentiated into curious cactus-like forms; and (5) *inner epiderm* of a single layer of small polygonal cells often escaping notice.

Perisperm.—The cells are small and collapsed with cuticularized outer membrane.

Endosperm.—This consists of one layer of thick-walled cells, containing oil and aleurone grains, together with a collapsed inner thin-walled tissue.

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[1] De la localisation des principes actifs des Cucurbitacées, Toulouse, 1893.

[2] Untersuchungen über das Siebröhren-System der Cucurbitaceen, Berlin, 1884.

MICROSCOPIC CHARACTERS OF CUCURBITACEOUS SEEDS IN CROSS SECTION

	Outer epiderm (palisade layer) on flat side of seed			Subepiderm on flat side of seed		Sclerenchyma cells	Outer parenchyma
	Max. height	Radial thickening	Contents	Cell layers	Walls		
Pumpkin (*Cucurbita Pepo*)	300 μ	branched at tip	starch	several	thin, porous	isodiametric*	cactus-like
Crookneck Squash (*C. Pepo verrucosa*)	300 μ	branched whole length	starch	several	thin, porous	isodiametric*	cactus-like
Scallop Squash (*C. Pepo Melopepo*)	300 μ	branched whole length	starch	several	thin, porous	isodiametric*	cactus-like
Winter Squash (*C. maxima*)	300 μ	branched whole length	starch	several	thin, porous	isodiametric*	cactus-like
Musk Squash (*C. moschata*)	530	branched, variously	starch	several	thin, porous	isodiametric*	cactus-like
Cucumber (*Cucumis sativus*)	160	pointed, broad	colorless	one*	thick, porous	isodiametric*	spongy
Muskmelon (*C. Melo*)	200	pointed, narrow	colorless	several*	thick, porous	isodiametric*	spongy, porous
Watermelon (*Citrullus vulgaris*)	400	pointed †	brown or colorless	many ‡	thick, porous	isodiametric	spongy, porous
Cassabanana (*Sicana odorifera*)	250	pointed, narrow	colorless	several*	thick, porous	isodiametric*	simple
Balsam Pear (*Momordica charantia*)	60	no thickening	nearly colorless	several	thick	several layers ‡	spongy, porous, contains starch
Dish-Cloth Gourd (*Luffa* spp.)	30–60	columnar	brown	several ‡	various §	radially elongated	spongy
Wax Gourd (*Benincasa hispida*) Type I	nearly isodiametric	no thickening	colorless	many ‡	thick, porous	isodiametric, two layers	spongy
Wax Gourd (*Benincasa hispida*) Type II	250	pointed †, narrow	colorless	many ‡	thick, porous	isodiametric, two layers	spongy

* Elongated in surface view. † Occasionally once-branched. ‡ Cells vary in size, shape, etc. § Outer layers thin, inner layer thick.

Cotyledon.—Two layers of *palisade cells* underlie the *inner epiderm*, the remainder of the *mesophyl* being of small characterless cells and procambium bundles. Throughout, oil and small (up to 10 μ) aleurone grains with globoids and crystalloids are present.

The characters of the seed of the chayote, as are described under that head, are radically different from those of the *Cucurbitæ* tribe.

COMPARATIVE CHEMICAL COMPOSITION.—Proximate analyses of the characterless pulp of the pumpkin, squash, cucumber, and certain exotic species show little differentiation. More striking results are obtained on the melons, which have a richly saccharine juice. Cantaloupe juice may contain over 5 per cent of *sucrose* alone in addition to a certain amount of *reducing sugars*, and watermelon juice may contain 7 per cent of total sugars, reducing sugars apparently predominating.

The *acidity* in all the members of the group is low, seldom exceeding 0.15 per cent calculated as citric.

The crystalline *globulins* of the squash and muskmelon seeds have long been the subject of research. They contain between 18 and 19 per cent of nitrogen and about 1 per cent of sulphur. Hirohata [1] found that the crystalline globulins of 38 species and varieties belonging to 8 genera differed little in chemical and physical characters.

Oils from the seeds of the species examined are semi-drying, the chief fatty acids being linolic, oleic, and palmitic in the order named.

PUMPKIN

Cucurbita Pepo L.

Fr. Pépon. Sp. Calabaza. It. Zucca. Ger. Grosse-Kürbis.

Early explorers of America state that the aborigines cultivated pumpkins with Indian corn as is today a common practice. Wittmack found pumpkin seeds in Peruvian tombs believed to antedate the discovery of America.

In culinary properties the pumpkin resembles closely the Winter squash and like it is used as a vegetable either boiled or baked. The filling of pumpkin pie as made in the United States consists of sifted pumpkin pulp, milk, eggs, sugar, and ginger and other spices. Pumpkin seeds contain a nutritious and palatable kernel.

MACROSCOPIC STRUCTURE.—Although perhaps the largest of fruits, the pumpkin is morphologically a *berry*. It varies greatly in shape but commonly is flattened-globose with about twenty longitudinal grooves. The color is yellow, orange, or greenish. Like the Winter quash, the fruit is hollow with a yellow rind often several centimeters hick and slimy fibers tangled about numerous whitish, flattened, elliptical, margined *seeds*, and the peduncle is not broadened where it joins the fruit.

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[1] Z. physiol. Chem. 1932, **212**, 1.

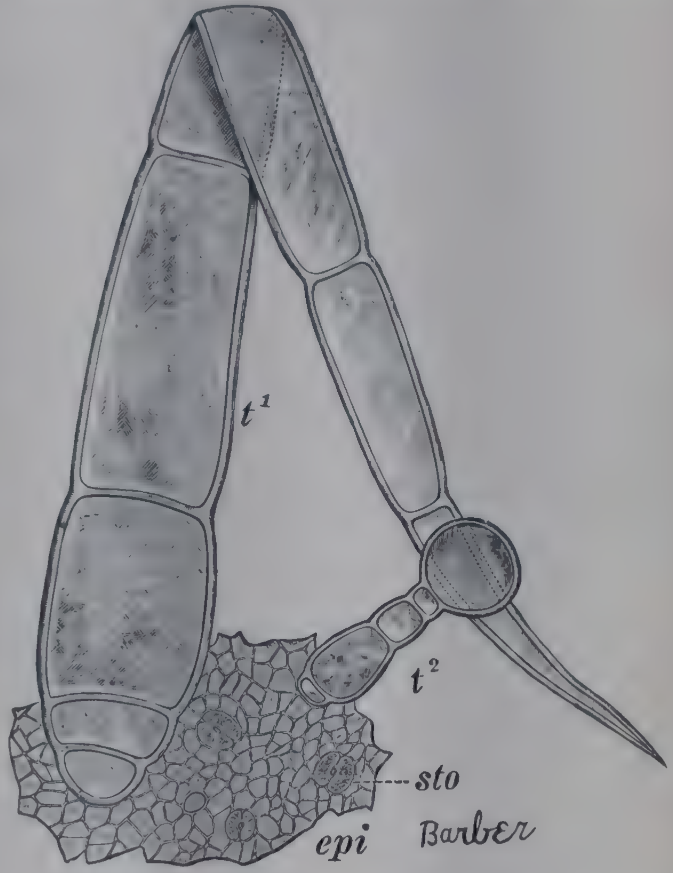

FIG. 132.—Pumpkin. *epi* immature epicarp in surface view: t^1 jointed hair, t^2 capitate hair, *sto* stoma. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE. Pericarp.—The layers of the mature fruit are (1) *epicarp* of cuticularized cells up to 50 μ high, with thickened, bright yellow outer and radial walls, stomata, and hair scars; (2) *hypoderm*, many cells thick, of small isodiametric cells; (3) *outer mesocarp* of cells larger than in hypoderm; (4) *middle mesocarp* of large cells containing starch grains; (5) *inner mesocarp* of cells smaller than in preceding layer, in the inner part forming with numerous fibro-vascular bundles a disorganized tissue; and (6) *endocarp* of longitudinally elongated cells which strip from the spermoderm as a thin skin.

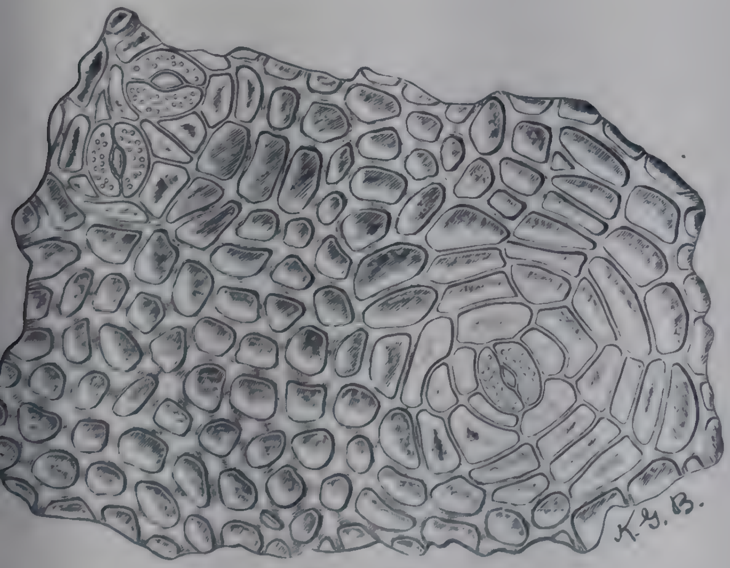

FIG. 133.

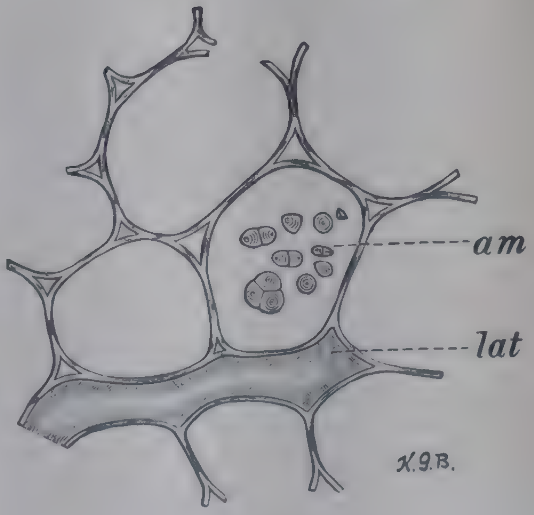

FIG. 134.

FIG. 133.—Pumpkin. Epicarp in surface view. × 320. (K.B.W.)

FIG. 134.—Pumpkin. Mesocarp showing *am* starch grains and *lat* latex tube. × 160. (K.B.W.)

On the immature fruit (Fig. 132), long (up to 2 mm.), exceptionally broad, jointed, *pointed hairs* (t^1) and small *capitate hairs* (t^2) are present. About the stomata of the mature fruit (Fig. 133) the radiating cells of the epicarp are colorless. The *starch grains* (Fig. 134, *am*) of the mesocarp vary up to 10 μ and occur singly, in twins, and triplets. *Latex tubes* (Fig. 134, *lat*), *sieve tubes* independent of fibro-vascular bundles, and bicollateral *fibro-vascular bundles* are distributed through the mesocarp.

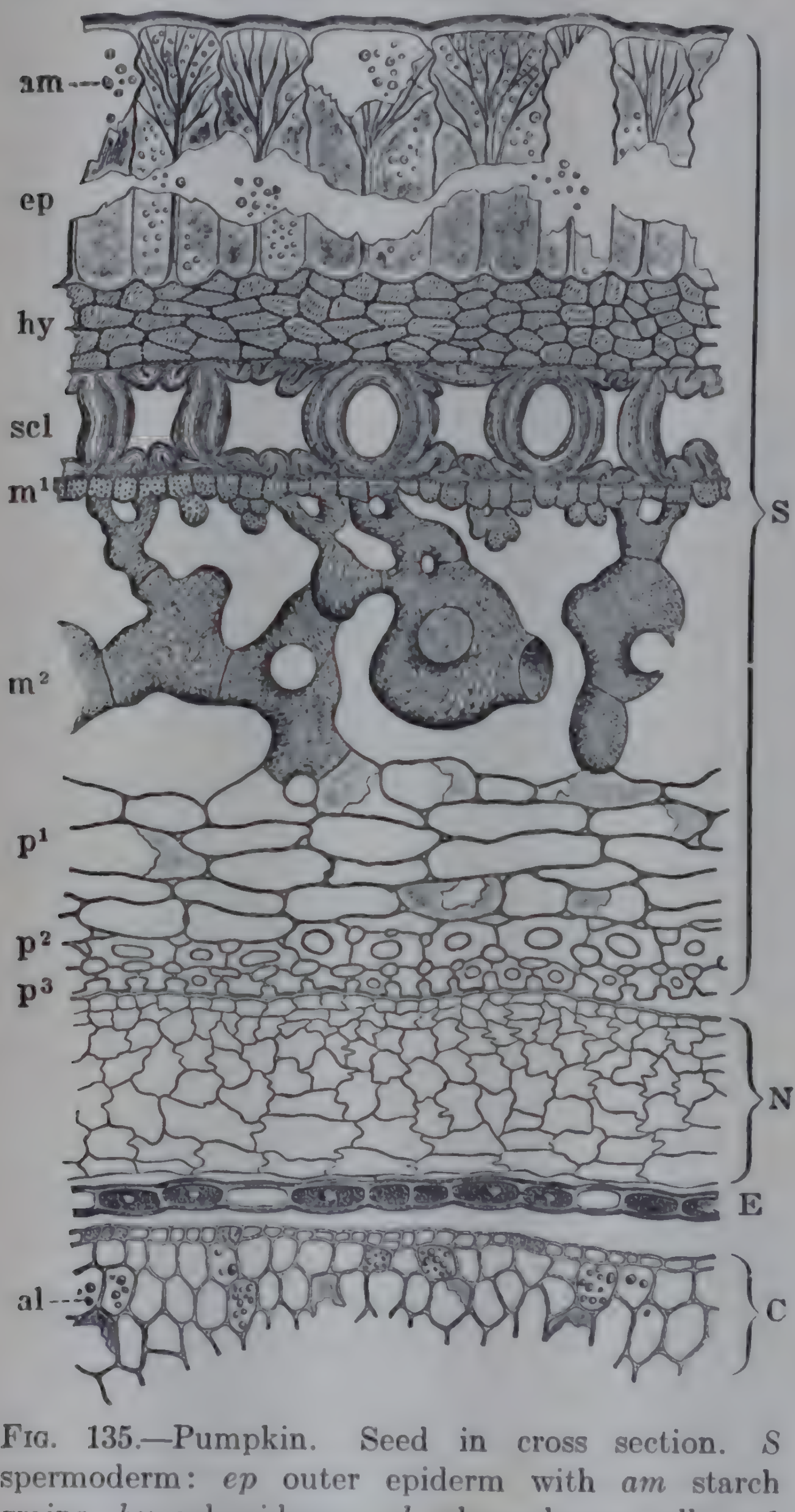

FIG. 135.—Pumpkin. Seed in cross section. *S* spermoderm: *ep* outer epiderm with *am* starch grains, *hy* subepiderm, *scl* sclerenchyma cells, m^1 porous cells, m^2 cactus-like cells, p^1 and p^2 inner parenchyma, p^3 inner epiderm. *N* perisperm. *E* endosperm. *C* cotyledon with *al* aleurone grains. × 160. (K.B.W.)

Spermoderm (Fig. 135, *S*; Fig. 136).—No less than eight layers are well differentiated: (1) *outer epiderm* (*ep*) of prismatic cells up to 300 μ high, with a rib on each radial wall branching toward the tip, containing small starch grains (*am*) up to 7 μ; (2) *subepiderm* (*hy*) of small porous cells forming a close layer several cells thick; (3) *sclerenchyma layer* (*scl*) of large longitudinally elongated cells, with broad lumen, and wavy walls, isodiametric in cross section; (4) small *porous cells* (m^1); (5) large, reticulated, *cactus-like cells* (m^2) forming a spongy tissue; (6) *parenchyma* (p^1); (7) *spongy parenchyma* (p^2); and (8) *inner epiderm* (p^3) similar to the preceding but of smaller cells.

Perisperm (Figs. 135 and 136, *N*).—This consists of an *epiderm* of ongitudinally elongated cells and several layers of isodiametric cells, all thin-walled.

Endosperm (Figs. 135 and 136, *E*).—A single layer of *aleurone cells* with well-marked nucleii.

Cotyledon (Fig. 135, *C*).—The *epidermal cells* are small. Two layers of *palisade cells* underlie the inner epiderm. The cell contents are aleurone grains (*al*), up to 6 μ, with globoids and crystalloids, and oil.

Chief Structural Characters.—Fruit at maturity large, hollow, melon-shaped, yellow, orange, or green. Seeds colorless, margined, flattened, thick, in slimy mass of bundles. Spermoderm leathery; perisperm and endosperm thin; embryo bulky.

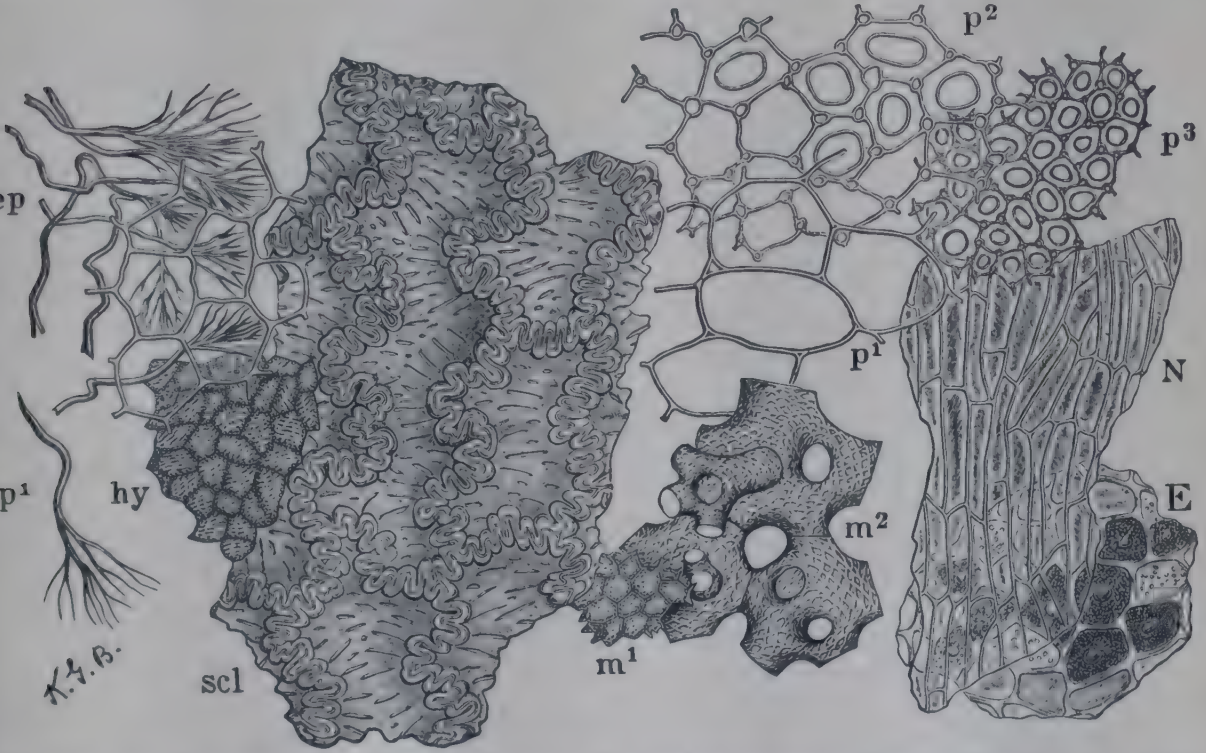

FIG. 136.—Pumpkin. Elements of seed in surface view. Spermoderm: *ep* outer epiderm, ep^1 isolated radial wall thickening, *hy* subepiderm, *scl* sclerenchyma cells, m^1 porous cells, m^2 cactus-like cells, p^1 and p^2 inner parenchyma, p^3 inner epiderm. *N* perisperm. *E* endosperm. × 160. (K.B.W.)

Pericarp cells yellow, 50 μ high; hypoderm of small isodiametric cells; outer mesocarp of larger cells; middle mesocarp of still larger cells containing starch grains (10 μ); inner mesocarp, partly disorganized; tangle of bundles, latex tubes, and sieve tubes throughout mesocarp. Outer epiderm of spermoderm with rods branching only toward the tip; subepiderm of small porous cells; sclerenchyma cells large with broad lumen; cactus-like cells characteristic. See also table p. 431.

CHEMICAL COMPOSITION.—Analyses by Storer[1] show the distribution of food elements in the different parts. These analyses, together with those reported by Lindsey[2] and by Yoshimura and Nishida[3] of the whole fruit, by Lindsey, Smith, and Beals[4] of the seeds, and by Wicke and Weiske[5] of the seed cake after expressing the oil, follow:

COMPOSITION OF PUMPKIN AND ITS PARTS

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
Storer:							
Common round	1						
Flesh........		92.41	0.87	0.10	4.80	1.11	0.71
Rind........		84.44	2.90	0.49	6.75	3.92	1.50
Seeds and fiber		75.94	6.32	7.13	5.21	3.74	1.66
Small round....	1						
Flesh........		94.37	0.95	0.14	3.05	0.86	0.63
Rind.........		88.01	2.63	0.49	4.67	2.97	1.23
Seeds and fiber		77.79	5.68	6.71	4.34	4.12	1.36
Lindsey:							
Whole fruit.....	4	87.53	1.92	1.49	6.25	1.84	0.96
Y. and N.:							
Whole fruit.....		82.00	2.38	0.45	12.34	1.58	1.25
L., S., and B.:	2						
Seeds..........		12.0	28.1	33.0	6.5	17.3	3.1
W. and W.:							
Seed cake.......	....	0.00	43.75	26.78	15.41	5.59	8.47

On the following page is a summary of analyses of the "edible portion" or solid fruit flesh as given by Atwater and Bryant[6] and of the same material canned, by McElroy and Bigelow.[7]

Relation of Composition to Ripeness.—Arasimovich[8] found that both the pumpkin and the Winter squash differ from related species in that the seven-days-old fruit contains 3 to 7.5 per cent of sugars, which is as much as the ripe. Dextrose is always in excess over levulose, and sucrose is not always present.

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[1] Bussey Inst. 1877, Bul. **83**.

[2] Massachusetts Agr. Exp. Sta. 1917, Bul. **174**, 55.

[3] J. Chem. Soc. Japan 1924, **45**, 49.

[4] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[5] Landw. Vers.-Stat. 1895, **46**, 371.

[6] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[7] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, 1138.

[8] Bul. Appl. Bot. Genetics Plant-Breed. (Leningrad) 1933, Ser. III, No. **1**, 73.

COMPOSITION OF SOLID FRUIT FLESH OF PUMPKIN

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Salt
		%	%	%	%	%	%	%
Raw: . . .	3							
Min. . .		92.3	0.9	0.1	3.9	0.9	0.6	. . . .
Max. . .		94.4	1.1	0.2	5.9	1.1	0.7	. . . .
Aver. .		**93.1**	**1.0**	**0.1**	**5.2**	**1.2**	**0.6**	. . . .
Canned: .	5							
Min. . .		89.38	0.46	0.06	3.55	0.62	0.44	0.01
Max. .		94.34	0.92	0.40	7.34	1.44	0.55	0.04
Aver. .		**92.72**	**0.65**	**0.14**	**4.90**	**1.08**	**0.51**	**0.02**

Proteins.—See Winter Squash.

Nitrogenous Bases.—Yoshimura and Nishida[1] extracted from 16 kilos of pumpkin flesh the following: *adenine* as hydrochloride 0.25, *arginine* as nitrate 1.58, and *trigonelline* as hydrochloride 0.50 grams.

Fatty Oil of Seed. *Physical and Chemical Values.*—Schattenfroh,[2] Poda,[3] Hooper,[4] and Power and Salway[5] give figures for pumpkin seed oil corresponding in general with those of squash seed oil.

VALUES OF PUMPKIN SEED OIL

	Sp. gr. 15° C.	Ref. index 25° C.	Sa-pon. No.	Io-dine No.	Reichert-Meissl No.	Hehner No.	Acetyl No.	Fatty acids, m. pt.	Fatty acids, titer	Acid No.
								°C.	° C.	
Schattenfroh.	0.923	. . . . . .	188.7	113.4	. . . .	96.2	27.2	26.0	. . . .	1.27
Poda:										
Min.	0.923	1.4723	188.4	122.8	. . . .	. . . .	. . . .	28.4	. . . .	. . . .
Max.	0.925	1.4738	190.2	130.7	. . . .	. . . .	. . . .	29.8	. . . .	. . . .
Hooper:										
Min.	0.926	. . . . . .	195.7	126.0	0.43	. . . .	. . . .	. . . .	31	0.9
Max.	0.928	. . . . . .	196.2	129.6	0.52	. . . .	. . . .	. . . .	32	12.8
P. and S.	0.922*	. . . . . .	189.4	119.7	. . . .	. . . .	. . . .	. . . .	. . . .	3.4

* 20°/20°.

Composition.—Following are calculated percentages of glycerides in the oil as obtained by Power and Salway[1] and by Riebsomer and Nesty:[2]

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[1] Loc. cit.

[2] Z. Nahr. Unters. Hyg. Waarenk. 1894, **8**, 202.

[3] Z. Unters. Nahr.-Genussm. 1898, **1**, 625.

[4] J. Soc. Chem. Ind. 1908, **27**, 906.

[5] J. Am. Chem. Soc. 1910, **32**, 346.

	R. and N.	P. and S.
	%	%
Glycerides of:		
Palmitic acid..	6.5	30
Stearic acid...	5.4	
Oleic acid....	37.5	25
Linolic acid...	42.2	45
	91.6	100

Phytosterol.—Power and Salway[1] found in pumpkin seed a small amount of a phytosterol ($C_{27}H_{46}O$) melting at 162 to 163° C.

Acids.—In pumpkin-seed cake, containing 8.7 per cent of oil, Power and Salway[1] found 5 per cent of resin from which they isolated a new *monocarboxylic acid,* with the formula $C_{25}H_{51}OCO_2H$, melting at 99° C. They also found a small quantity of *salicylic acid.*

Carbohydrates.—At maturity the fruit flesh in addition to *starch* (see Microscopic Structure) contains a considerable amount of *soluble carbohydrate matter.* Lindsey[3] found that about 18 per cent of the dry matter consisted of sugars of which one-third was *sucrose.* Tikhmenev[4] obtained *levulose* and *dextrose,* but no galactose, mannose, or arabinose, from unripe pumpkin flour by boiling with water, after extraction with fat solvents and alcohol.

Enzymes.—*Peroxidase* was first discovered in the horse-radish and the pumpkin seed by Bach.[5] It together with *oxygenase,* as shown by Chodat and Bach,[6] make up what was once considered to be a single enzyme known as oxidase.

Mineral Constituents.—Wolff[7] found 4.89 per cent of ash and the following amounts of mineral constituents as percentages of the ash:

K_2O	NaO	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%
19.48	21.13	7.74	3.37	2.60	32.85	2.37	7.34	0.43

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[1] Loc. cit.

[2] J. Am. Chem. Soc. 1934, **56**, 1784.

[3] Loc. cit.

[4] J. Appl. Chem. (U.S.S.R.) 1933, **6**, 320; Chem. Abs. 1934, **28**, 3101.

[5] Ber. 1903, **35**, 600.

[6] Ibid. 1903, **36**, 606.

[7] Aschenanalysen.

Minor Mineral Constituents. *Iron.*—Fruit 11 mg. per kilo, fresh basis (Peterson d Elvehjem).[1]

Manganese.—Fruit 4.5 mg. per kilo, dry basis (Peterson and Skinner).[2]

Copper.—Seed coats, trace (Power and Salway).[3] Fruit 1.1 mg. per kilo, fresh asis (Guérithault).[4] Fruit 0.3 mg. per kilo, fresh basis (Lindow, Elvehjem, and eterson).[5]

Iodine.—None (Winterstein).[6]

SCALLOP SQUASH

Cucurbita Pepo var. *condensa* Bailey (part) = var. *Melopepo* L.

Fr. Pâtisson. Ger. Melonenkürbis.

This variety, the pineapple squash, the vegetable marrow, and the crookneck squash yield fruits eaten as Summer vegetables.

MACROSCOPIC STRUCTURE.—The *fruit* differs from the pumpkin chiefly in that it is whitish, flattened, with ten to fifteen scallops on the rim. Its flattened form distinguishes it from the pineapple squash, the upper half of which is conical, and the vegetable marrow which is oblong. At the tender, edible stage the hairs are still attached and the *seeds* are immature.

MICROSCOPIC STRUCTURE.—The structure is practically the same as that of the pumpkin, the only marked difference noted being that the rods on the radial walls of the *outer epiderm* of the spermoderm besides branching at the outer end, also branch along their entire length.

Chief Structural Characters.—Fruit flattened, scalloped.

Histological structure same as of pumpkin except that rods of outer epiderm of spermoderm branch along entire length. See also table p. 431.

CROOKNECK SQUASH

Cucurbita Pepo var. *condensa* Bailey (part) = var. *verrucosa* Naud.

Fr. Potiron à verrues. Ger. Warzenkürbis.

Although the crookneck squash is regarded as a variety of *C. Pepo* and according to L. H. Bailey the same variety as the scallop squash, the presence of a hard sclerenchyma tissue in the outer mesocarp suggests close relationship with the Winter squash.

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[1] J. Biol. Chem. 1928, **78**, 215.

[2] J. Nutrition 1931, **4**, 419.

[3] Loc. cit.

[4] Bul. soc. hyg. aliment. 1927, **15**, 386.

[5] J. Biol. Chem. 1929, **82**, 465.

[6] Z. physiol. Chem. 1918, **104**, 54.

MACROSCOPIC STRUCTURE.—The crooked neck and the bottle-shaped body of the *fruit* distinguish this variety from all other varieties of *Cucurbita Pepo.* The blister-like warts distinguish it from the scallop squash. Blisters occur also on the Winter squash.

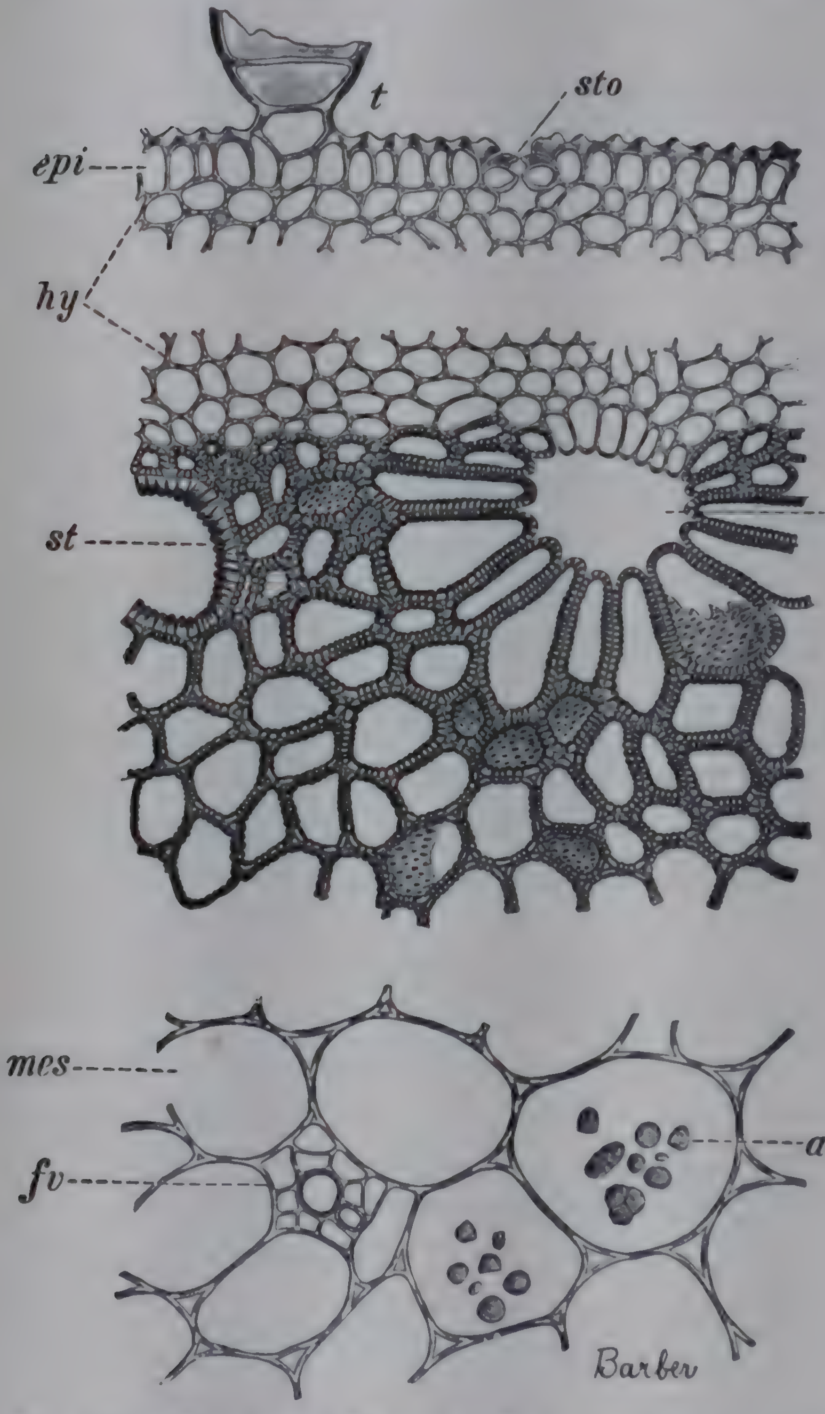

FIG. 137.—Crookneck Squash. Outer pericarp in cross section. *epi* epicarp with *t* hair and *sto* stoma; *hy* hypoderm; *st* outer mesocarp with *x* large intercellular space; *mes* middle mesocarp with *fv* vascular bundle and *am* starch grains. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE. Pericarp (Fig. 137).—The *epicarp* cells (*epi*) are somewhat shorter (up to 36 μ) than in the pumpkin and the much-thickened outer walls are depressed over each cell, causing the wavy appearance in cross section. The stomata (*sto*) are sunken. *Hairs* (*t*) such as occur on the pumpkin persist to maturity.

The sclerenchymatized cells of the *outer mesocarp* (*st*), often radiating about intercellular cavities (*x*), are highly characteristic. Because of this tissue the mature squash has a hard "shell" that resists decay.

Spermoderm.—The rods on the radial walls of the *outer epiderm,* like those of other Summer squashes, besides branching at the outer end as in pumpkin also branch along their entire length.

Chief Structural Characters.—Fruit elongated obovoid, crook-ecked, with warts.

Epicarp cells, 36 μ, with depressed outer walls; outer mesocarp trongly sclerenchymatized. Otherwise like scallop squash. See also able p. 431.

WINTER SQUASH

Cucurbita maxima Duch.

Fr. Potiron. Sp. Zucca. Ger. Speisekürbis.

Under this head are included numerous cultivated varieties, including he Hubbard, the turban, and others of various shapes, used when fully ipe in place of the pumpkin. It does not include the Winter crookneck squash (*C. moschata* Duch.). The species is believed to be a native of the Old World and does not cross readily, if at all, with *C. Pepo.*

MACROSCOPIC STRUCTURE.—Some varieties have fruits as large as those of the pumpkin. The surface is commonly green and warty with indistinct longitudinal grooves. There are yellow and orange varieties which color also characterizes the flesh. The Hubbard squash is of large size, somewhat pointed at both ends. Turban squashes are characterized by the protrusion of the fruit proper beyond the receptacle. Other varieties are oblong and variously shaped. Like the pumpkin, the fruit is hollow with seeds entangled in bundles.

MICROSCOPIC STRUCTURE.—Not noticeably different from that of the crookneck squash.

Chief Structural Characters.—Fruit of various shapes and sizes, green, yellow, or orange. Seed like pumpkin seed.

Histological structure same as of crookneck squash.

CHEMICAL COMPOSITION.—On the next page are a summary of analyses of the edible portion of the squash reported by Atwater and Bryant,[1] an analysis of fresh squash, grown in the Philippines, by Agcaoili,[2] and two analyses of canned squash by McElroy and Bigelow.[3]

Changes in Composition During Ripening and Storage.—The increase in reducing sugars during ripening is noted by Cordner and Matthews,[4] who also show that storage at 2 to 4° C. prevents loss of carbohydrates.

Relation of Composition to Ripeness.—Arasimovich[5] found that both the pumpkin and the Winter squash differ from related species in

[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Philippine J. Sci. 1916, **11**, 91.

[3] U. S. Dept. Agr., Div. Chem. 1893, Bul. **13**, 1139.

[4] Proc. Am. Soc. Hort. Sci. 1931, **27**, 520.

[5] Bul. Appl. Bot. Genetics Plant-Breed. (Leningrad) 1933, Ser. III, No. **1**, 73.

COMPOSITION OF SOLID FRUIT FLESH OF SQUASH

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash	Salt
		%	%	%	%	%	%	%
Raw								
A. and B.:	10							
Min.......		78.9	0.6	0.1	3.5*	0.5†	0.4	....
Max......		95.2	3.1	1.4	16.1*	1.2†	1.6	....
Aver......		**88.3**	**1.4**	**0.5**	**9.0***	**0.8†**	**0.8**	....
Agcaoili.....		87.20	1.33	0.43	9.33	0.70	1.01	....
Canned								
McE. and B.:	2							
I.........		85.63	0.24	0.06	13.60	0.28	0.19	0.01
II........		87.53	0.85	0.45	9.47	1.08	0.62	0.03

* Includes fiber. † 5 samples.

that immature fruit contains as much sugar as ripe. Dextrose always exceeds levulose, and sucrose is not always present.

Relation of Composition to Quality.—Cummings and Stone [1] measure the culinary value of Hubbard squash by the protein content on the dry basis which varied from 10.5 to 11.3, aver. **11.4** per cent, when the quality was good and from 10.8 to 15.9, aver. **12.8** per cent, when it was poor or the fruit was immature.

Proteins.—Barbieri [2] prepared a protein from squash seeds differing somewhat in composition from the globulin of later investigators. Grübler[3] extracted a crystalline *globulin* by means of warm dilute brine and other saline solutions. Chittenden and Hartwell[4] prepared a globulin in crystalline, spheroidal, and amorphous forms, agreeing closely in composition with that of Grübler, and Osborne[5] showed that the squash seed globulin had practically the same composition as the globulin of hemp seed, linseed, and castor bean.

The *Ultimate Composition of Squash Seed Globulin* by the authors named follows on the next page.

Jones and Gersdorff [6] isolated a globulin in the form of octohedral crystals.

Amino Acids of Squash Seed Globulin.—Abderhalden and Berghau-

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[1] Vermont Agr. Exp. Sta. 1922, Bul. **48**, 222.

[2] J. prakt. Chem. 1878, **18**, 102.

[3] Ibid. 1881, **23**, 97.

[4] J. Physiol. 1890, **11**, 435.

[5] Am. Chem. J. 1892, **14**, 662.

[6] J. Biol. Chem. 1923, **56**, 79; 1927, **75**, 213.

	Grübler	Chittenden and Hartwell			Osborne	
	Crystalline	Crystalline	Spheroidal	Amorphous	Crystalline	Spheroidal
	%	%	%	%	%	%
arbon.....	51.48	51.60	52.03	51.80	51.66	51.42
ydrogen...	6.76	6.97	6.93	6.94	6.89	6.83
itrogen...	18.14	18.80	19.08	18.72	18.51	18.64
ulphur....	0.96	1.01	1.04	1.01	0.88	0.90
xygen....	21.53	21.62	20.92	21.53	22.06	22.21
	98.87	100.00	100.00	100.00	100.00	100.00

en[1] obtained by hydrolysis quantitative results for 8 of the amino acids, otaling about 29 per cent. They found 13.4 per cent of glutamic acid, nd Osborne and Gilbert[2] the same year found 12.35 per cent. Osborne nd Clapp[3] extended the work as shown below.

Products of Hydrolysis of Squash Seed Globulin
(Osborne and Clapp)

	%
Glycocoll	0.57
Alanine	1.92
Valine	0.26
Leucine	7.32
Serine	.....
Cystine	0.23
Aspartic acid	3.30
Glutamic acid	12.35
Tyrosine	3.07
Phenylalanine	3.32
Proline	2.82
Tryptophane	+
Arginine	14.44
Lysine	1.99
Histidine	2.63
Ammonia	1.55

In squash seed globulin Jones, Gersdorff, and Moeller[4] obtained cystine 1.38 and tryptophane 3.01 per cent, and Hanke[5] tyrosine 3.05 and histidine 2.26 per cent.

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[1] Z. physiol. Chem. 1906, **49**, 15.

[2] Am. J. Physiol. 1906, **16**, 333.

[3] Ibid. 1907, **19**, 475.

[4] J. Biol. Chem. 1924, **62**, 183.

[5] Ibid. 1925, **66**, 489.

Fatty Oil of Seed.—Hooper[1] examined oil from seeds of squash grown in India, and Baughman and Jamieson[2] seeds of Hubbard squash grown in the United States.

Physical and Chemical Values.—Results by the authors named above follow:

VALUES OF SQUASH SEED OIL

	Sp. gr. 15° C.	Ref. index 25° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Acetyl No.	Fatty acids, titer	Acid No.	Unsapon. matter
								° C.		%
Hooper:										
Min....	0.919	......	194.9	88.7	0.47	....	....	32.0	6.4	....
Max....	0.926	......	197.1	133.4	0.67	....	....	38.0	17.7	....
B. and J..	0.918*	1.4714	191.5	121.0	0.37	0.39	27.8	29.8	0.5	1.06

* 25°/25°.

The wide range of iodine number reported by Hooper needs corroboration. Baughman and Jamieson obtained the following additional results: saponification number of insoluble acids 201.8, of liquid acids 201.7, of solid acids 210.3; mean molecular weight of insoluble acids 278, of liquid acids 278.1, of solid acids 266.8; soluble acids 0.33 per cent; insoluble acids 94.66 per cent; unsaturated acids 76.45 per cent; and saturated acids 18.37 per cent.

Composition of Squash Seed Oil.—The composition, as calculated by Baughman and Jamieson[3] from their own data, follows:

	%
Glycerides of:	
Arachidic acid, about..	0.04
Stearic acid..........	6.00
Palmitic acid.........	13.00
Oleic acid............	37.00
Linolic acid..........	44.00
Unsaponifiable matter....	1.00
	101.04

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[4] found 1.89 per cent, dry basis.

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[1] J. Soc. Chem. Ind. 1908, **27**, 906.

[2] J. Am. Chem. Soc. 1920, **42**, 152.

[3] Loc. cit.

[4] Philippine Agr. 1932, **21**, 53.

Colors.—Suginome and Ueno[1] found *cucurbitene*, $C_{40}H_{56}$, and *curbitaxanthin*, $C_{40}H_{56}O_2$, in the flesh, Zechmeister and Tuzson[2] ly β-carotene and a trace of α-carotene.

Minor Mineral Constituents. *Iron.*—Fruit, 3 samples, 70 to 130, aver. **105** mg. er kilo, dry basis (Remington and Shiver).[3] Hubbard squash 5.5 mg. per kilo, fresh asis (Peterson and Elvehjem).[4]

Manganese.—Fruit, 6 samples, 18.1 to 27.6, aver. **23.8** mg. per kilo, dry basis Remington and Shiver).[3]

Copper.—Fruit, fresh 1.1, dry basis 10.9 mg. per kilo (Guérithault).[5] Fruit, 6 mples, 11.0 to 15.3, aver. **13.2** mg. per kilo, dry basis (Remington and Shiver).[3] ubbard squash 0.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Edible portion fruit 2.1 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

Arsenic.—Fruit 0.09 mg. per kilo, fresh basis (Jadin and Astruc).[8]

MUSK SQUASH

Cucurbita moschata Duch.

Fr. Courge musquée. Ger. Moschuskürbis.

Winter crookneck, Canada crookneck, and cushaw are other names or plants of this species which Naudin separates into five botanical arieties.

MACROSCOPIC STRUCTURE.—The *fruit* varies in color from reen to orange, often with markings of another shade, and in form from isk-shaped to crooknecked. It is smooth, with or without longitudinal rooves, or more or less warty. The *seeds* also vary from those of he pumpkin type to much larger blue-margined forms.

MICROSCOPIC STRUCTURE.—The **Pericarp** is intermediate in structure between that of the pumpkin and Winter squash.

Spermoderm.—According to Kondo[9] the spermoderm differs from that of the pumpkin chiefly in having no thickenings on the radial walls of the cells of the *outer epiderm*—these varying up to 530 μ in height—and in having starch in the *inner parenchyma*.

Seeds furnished by the Office of Foreign Seed and Plant Introduction, Department of Agriculture, separate into two classes, both of the pumpkin type but differing in the following details: (1) those with thickenings on radial walls of the outer epiderm branching only a few times at top and occasionally once or twice at the bottom, and (2) those with very delicate thickenings extending over top and down on other side with only occasional, never feather-like, branches. The *subepiderm* and *sclerenchyma layer* of this second class also differ in not being of uniform height on the flat side of the seed.

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[1] Bul. Soc. Chem. Japan 1931, **6**, 221.
[2] Ber. 1934, **67B**, 824.
[3] J. Ass. Off. Agr. Chem. 1930, **13**, 129.
[4] J. Biol. Chem. 1928, **78**, 215.
[5] Compt. rend. 1920, **171**, 196.
[6] J. Biol. Chem. 1929, **82**, 465.
[7] Bul. soc. hyg. aliment. 1928, **16**, 457.
[8] Compt. rend. 1912, **155**, 291.
[9] Ber. Ohara Inst. Landw. Forsch. 1918, **1**, 288.

Chief Structural Characters.—Fruit green to orange, disk-shaped to crooknecked. Seeds varying from pumpkin type to large blue-margined forms.

Pericarp between pumpkin and Winter squash in structure. Outer epiderm of spermoderm with no radial thickenings or only delicate, sparingly branched thickenings (distinction from pumpkin). See also table p. 431.

CUCUMBER

Cucumis sativus L.

Fr. Concombre. Sp. Pepino. It. Cetriuolo. Ger. Gurke.

De Candolle has produced proof that the cucumber is a native of the Himalayas and has been cultivated in India for 3,000 years whence in ancient times it was introduced into the Far East and Europe.

It is commonly eaten raw or pickled, less often as a cooked vegetable.

MACROSCOPIC STRUCTURE.—Characteristic of the *fruit* are the elongated, rounded triangular form, the three locules, the more or less prominent spiny warts, and the white inner flesh. English forcing cucumbers are long and slender. At maturity the rind is yellow. A gelatinous material surrounds the *seeds* which at maturity are light buff, 1.5 cm. or less long, flattened, thin (up to 2 mm.), pointed at both ends, and without a margin.

MICROSCOPIC STRUCTURE. Pericarp (Figs. 138 and 139).—The layers are: (1) *epicarp* (*epi*) of cells up to 75 μ high with strongly thickened outer and radial walls, emergences, and hairs of two types; (2) *hypoderm* (*hy*) of rounded, loosely arranged parenchyma cells containing chlorophyl and beneath each emergence a group of porous sclerenchyma cells (*st*); (3) *outer*, (4) *middle*, and (5) *inner mesocarp* of thin-walled, rounded parenchyma cells, largest in the middle mesocarp, with numerous fibro-vascular bundles, latex tubes, and sieve tubes; and (6) *endocarp* of elongated, thin-walled cells.

At maturity the walls of the *epicarp* become brilliant yellow. A long jointed, *pointed hair* (*t*) occurs at the apex of each emergence, and numerous small, weak *capitate hairs* (Fig. 139), with usually four-celled ead, are distributed over the surface. Both forms are readily detached. he gelatinous appearance of the tissue about the seeds is due to tur- escence. The *endocarp* is firmly attached to the mesocarp and does ot cling to the seeds as in the pumpkin.

Spermoderm (Fig. 140, *S*).—Mature seeds should be sectioned while

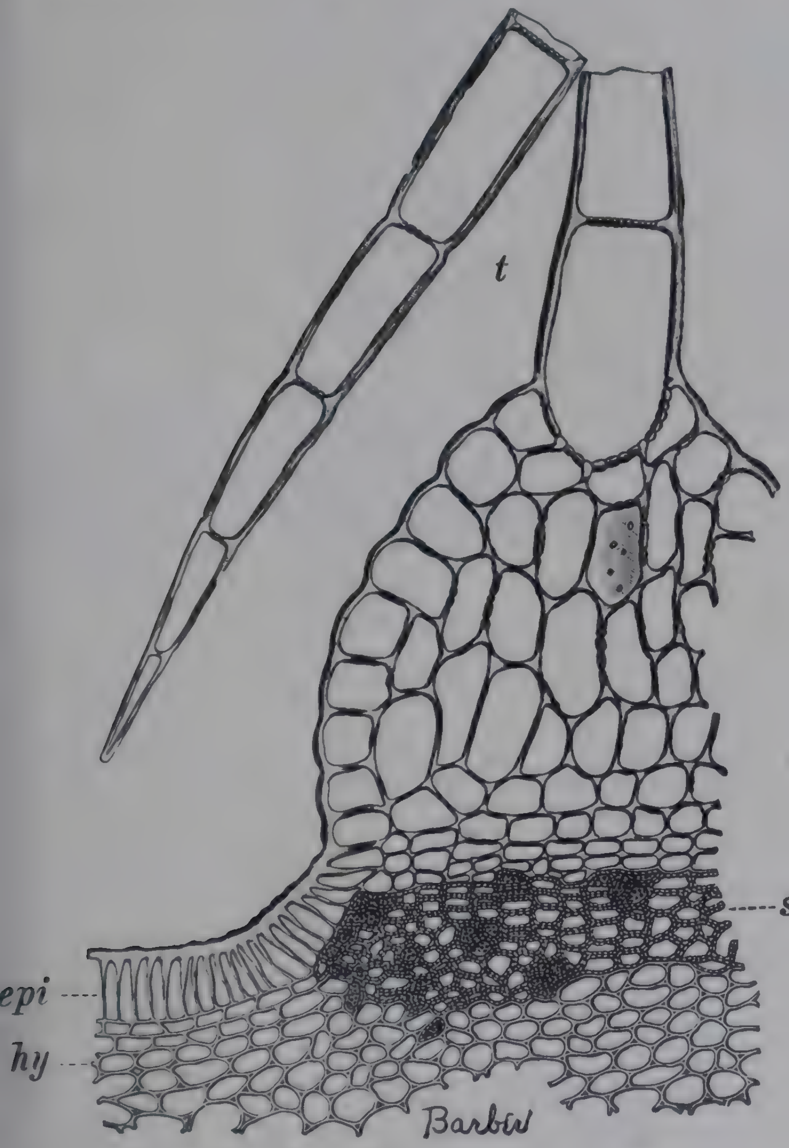

FIG. 138.

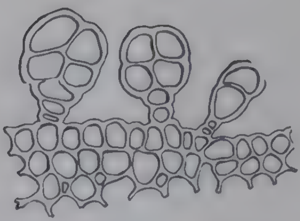

FIG. 139.

FIG. 138.—Cucumber. Outer pericarp in cross section. *epi* epicarp with emergence bearing *t* jointed hair; *hy* hypoderm with *st* sclerenchymatized cells beneath emergence. × 55. (K.B.W.)

FIG. 139.—Cucumber. Immature epicarp in cross section with hairs. × 160. (K.B.W.)

fresh, since on drying the outer wall of the outer epiderm is usually lost. The six layers are: (1) *outer epiderm* of cuticularized palisade cells (*ep*) up to 260 μ high on the sides of the seed, with broad, pointed thickenings; (2) *subepiderm* (*sub*; Fig. 141) of a single layer of longitudinally elongated cells with thick, sinuous, porous, sclerenchymatized walls; (3) *sclerenchyma layer* (*scl*; Fig. 142) of thick-walled, porous, longitudinally elongated cells, isodiametric in cross section; (4) *spongy parenchyma* (p^1); (5) *simple parenchyma* (p^2); and (6) *inner epiderm* of small elongated cells.

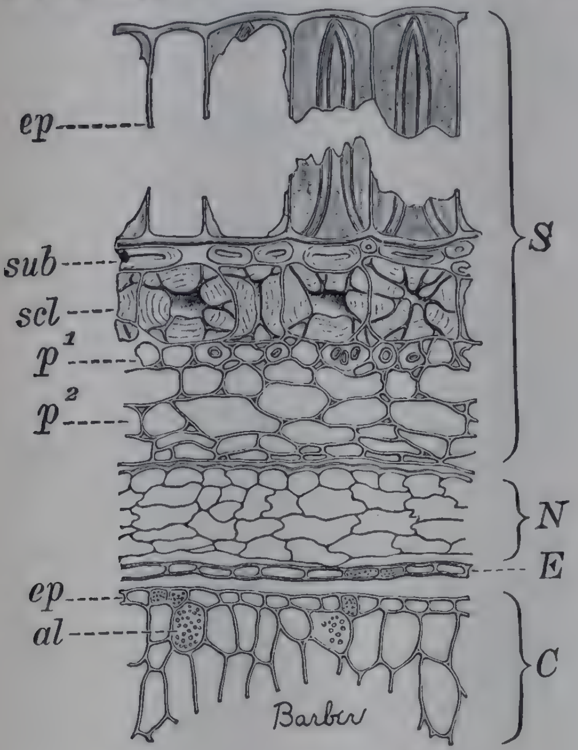

FIG. 140.

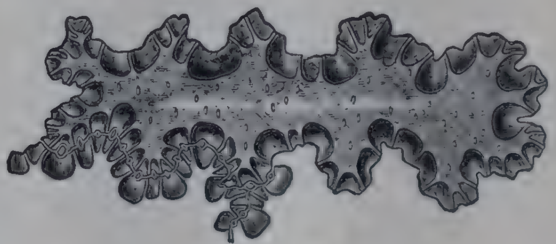

FIG. 141.

FIG. 140.—Cucumber. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *sub* subepiderm, *scl* sclerenchyma cells, p^1 outer and p^2 inner parenchyma. *N* perisperm. *E* endosperm. *C* cotyledon: *ep* epiderm, *al* aleurone grains. × 160. (K.B.W.)

FIG. 141.—Cucumber. Isolated subepidermal cell of spermoderm in surface view. × 300. (K.B.W.)

Tangential sections show that the thickenings of the cells of the *outer epiderm* occur on the two opposite radial walls of each cell at right angles to the axis of the seed. Treatment with chlorozinc iodine brings out three zones in the thickenings, an outer indistinct zone staining blue, a thin middle, weakly refractive zone also staining blue, and a strongly refractive core staining yellow.

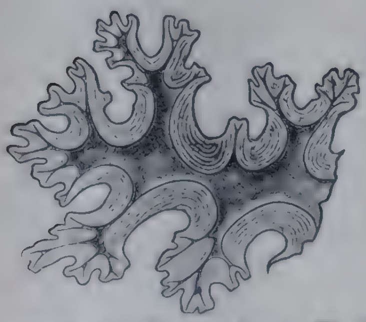

FIG. 142.—Cucumber. Half of isolated sclerenchyma cell in surface view. ×300. (K.B.W.)

Even in green cucumbers, the *sclerenchyma layer* is striking in surface view (Fig. 142) because of its thick walls and the interlocking branches.

Perisperm (Fig. 140, *N*), **Endosperm** (*E*), and **Cotyledon** (*C*) are of the usual cucurbitaceous type.

CHIEF STRUCTURAL CHARACTERS.—Fruit elongated, warty, rounded-triangular with seeds embedded in the gelatinous inner mesocarp. Seeds light buff, thin, pointed, without margin.

Epicarp of palisade cells (75 μ), elongated, jointed, pointed hair on each emergence, capitate hairs elsewhere; hypoderm under emergence of porous sclerenchyma cells; mesocarp characterless. Outer epiderm of spermoderm with broad, pointed thickenings; subepiderm of single layer of longitudinally elongated, thick-walled cells; sclerenchyma layer of thick-walled, elongated cells. See also table p. 431.

CHEMICAL COMPOSITION.—Dahlen [1] and Heinze [2] analyzed whole cucumbers of different sizes and consequently of different degrees of ripeness. Atwater and Bryant [3] summarize analyses of the edible portion of 4 samples, Agcaoili [4] gives an analysis of the edible portion of 1 sample, and v. Schleinitz [5] of peeled and unpeeled cucumbers.

Composition of Cucumber

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%
Dahlen:								
Small	95.44	0.93	0.03	2.66	1.51	....	0.50	0.44
Large	94.17	1.53	0.06	3.07	0.79	....	0.69	0.48
Heinze:								
Small (80–90g.)								
Min.	96.63	0.69	0.08	....	0.00	0.05	0.55	0.32
Max.	96.75	0.98	0.10	....	0.00	0.13	0.64	0.34
Aver.	**96.63**	**0.81**	**0.09**	**1.44**	**0.00**	**0.10**	**0.58**	**0.34**
Med. (170–190g.)								
Min.	95.40	0.56	0.08	....	0.11	0.05	0.55	0.38
Max.	96.04	0.94	0.10	....	0.98	0.13	0.68	0.53
Aver.	**95.82**	**0.68**	**0.09**	**1.58**	**0.66**	**0.09**	**0.65**	**0.42**
Large (857–897g.)								
Min.	95.12	0.69	0.22	....	0.55	0.11	0.72	0.40
Max.	95.23	0.71	0.27	....	0.57	0.12	0.76	0.43
Aver.	**95.18**	**0.70**	**0.24**	**2.06**	**0.56**	**0.12**	**0.74**	**0.42**
A. and B.								
Edible part								
Min.	94.7	0.5	0.1	2.2*	....	....	0.5	0.3
Max.	96.3	0.9	0.5	4.0*	....	....	0.9	0.6
Aver.	**95.4**	**0.8**	**0.2**	**3.1***	....	....	**0.7†**	**0.5**
Agcaoili	94.14	0.52	0.19	2.39	....	....	0.30	0.46
v. Schleinitz:								
Peeled	97.66	0.55§	0.17	0.89	....	....	0.30	0.43
Unpeeled	97.32	0.64‖	0.16	0.96	....	....	0.43	0.49

* Includes fiber. † 2 samples. § Pure protein 0.39%. ‖ Pure protein 0.47%.

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[1] Landw. Jahrb. 1875, **4**, 613.

[2] Z. Unters. Nahr.-Genussm. 1903, **6**, 529, 577.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[4] Philippine J. Sci. 1916, **11**, 91.

[5] Landw. Jahrb. 1918, **52**, 131.

Composition of Seed.—Einhorn, Milski, and Kalashnikov[1] found in a single sample of air-dry seeds:

Water	Protein	Fat	Sugars, starch, etc.	Pentosans	Cellulose	Pectins	Phytin	Lecithin	Ash	P_2O_5
%	%	%	%	%	%	%	%	%	%	%
8.0	29.69	31.47	1.88	4.67	13.89	0.59	1.1	2.60	3.92	2.25

Nitrogenous Bases.—From the hot water extract of 22 kilos of fresh cucumbers Yoshimura and Nishida[2] isolated: *adenine* as hydrochloride 0.27 and *trigonelline* as aurichloride 0.5 gram and obtained positive reactions for *arginine.*

Fatty Oil of Seed. *Physical and Chemical Values.*—Two samples of cucumber seed oil examined by Hooper[3] and one, obtained by extraction, examined by Einhorn, Milski, and Kalashnikov,[4] showed the following values:

	Sp. gr. 15° C.	Ref. index 25° C.	Solid. Pt.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Acetyl No.	Fatty acids, titer	Acid No.
			° C.						° C.	
Hooper:										
I.	0.924	. . . . .	. . . . .	195.2	117.6	0.52	. . . .	. . . .	35.5	11.5
II.	0.923	. . . . .	. . . . .	196.9	118.5	0.52	. . . .	. . . .	35.5	10.7
E. M. and K.	0.9251	1.4761	−3.5	191.1	115.3	1.05	0.87	16.6	. . . . .	3.53

Composition.—The last-named authors found unsaponifiable matter 1.91 per cent and the following amounts of fatty acids: stearic 3.72, palmitic 6.79, oleic 58.49, and linolic 22.29 per cent.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[5] reports 3.05 per cent, dry basis.

Enzymes.—The presence of an ereptic enzyme, located chiefly in the endocarp and most abundant in the mature fruit, has been demonstrated by Chopra and Roy.[6]

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[1] Masl.-Zhir. Delo 1929, **45**, 44; Chem. Abs. 1930, **24**, 2625.

[2] J. Chem. Soc. Japan 1924, **45**, 49.

[3] J. Am. Chem. Soc. 1908, **27**, 906.

[4] Loc. cit.

[5] Philippine Agr. 1932, **21**, 53.

[6] Indian J. Med. Res. 1933, **21**, 17.

Mineral Constituents.—Wolff[1] found 6.3 per cent of ash in fresh cucumbers, containing 95.6 per cent of water, and the following amounts of mineral constituents recalculated to percentages of the ash:

K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%
38.1	9.5	6.4	3.2	19.0	6.3	7.9	6.4

Minor Mineral Constituents. *Iron.*—Green fruit 3.5 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Manganese.—Seed 2.5 mg. per kilo, dry basis (Wester).[3] Green fruit 48.4 mg. per kilo, dry basis (Peterson and Skinner).[4]

Copper.—Fruit, fresh 2.3, dry basis 50 mg. per kilo (Guérithault).[5] Green fruit 0.6 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[6]

Zinc.—Fruit 1.6 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

MUSKMELON

Cucumis Melo L.

Fr. Melon musqué. Sp. Melon almizeleno. It. Mellone.
Ger. Zuckermelone.

The parent plant, a native of Asia and Africa, produces small fruits. Naudin[8] divides the varieties into 10 groups which freely hybridize with one another: (1) *agrestis*, wild form; (2) *cantalupensis*, cantaloupe; (3) *reticulatus*, netted melons; (4) *saccharinus*, sugar and pineapple melons; (5) *inodorus*, Winter melons; (6) *flexuosus*, serpent melon, ornamental and used for preserves; (7) *acidulus*, cucumber melon; (8) *Chito*, orange melon, used for preserves; (9) *Dudaim*, fragrant ornamental; and (10) *erythræus*, Persian melon, scarlet-fruited ornamental. In some sections of the United States the term cantaloupe is incorrectly applied to the netted or nutmeg melons, the true cantaloupe being grown chiefly in Europe, often under glass. The cassaba melon, a Winter melon introduced from Asia Minor, is now extensively grown in California; a rather small fruited variety, known as "Honey-dew," has a whitish skin.

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[1] Aschenanalysen.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Biochem. Z. 1921, **118**, 158.

[4] J. Nutrition 1931, **4**, 419.

[5] Compt. rend. 1920, **171**, 196.

[6] J. Biol. Chem. 1929, **82**, 465.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

[8] Ann. sci. nat. 4 ser., 1859, **2**.

MACROSCOPIC STRUCTURE.—In form the *melons* are commonly globoidal or elongated with about ten more or less distinct narrow longitudinal grooves producing an appearance known as "melon-shape." The surface may bear numerous cork-like reticulations (nutmeg or netted melons) or may be smooth or merely wrinkled (true cantaloupe, cassaba melon, etc.). The color of the rind and especially of the flesh varies from white or green to yellow, orange, or red. The *seed* is like that of the cucumber in form and size but is somewhat yellower.

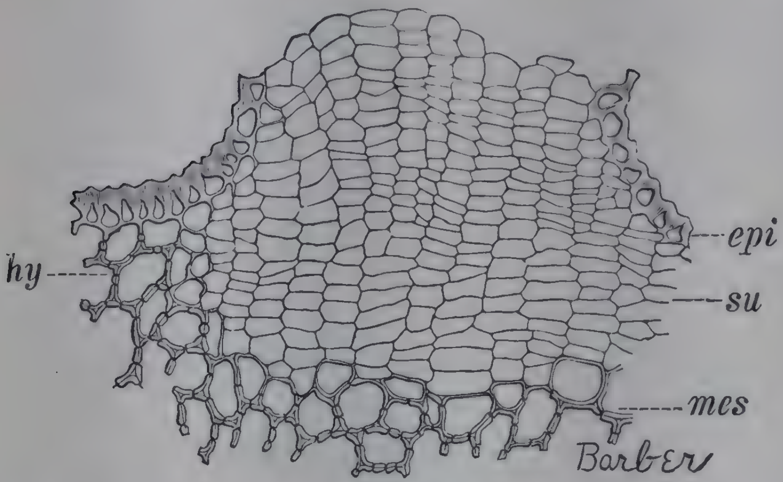

Fig. 143.—Muskmelon. Rib of pericarp in cross section. *epi* epicarp; *su* cork cells; *hy* hypoderm; *mes* outer mesocarp. × 50. (K.B.W.)

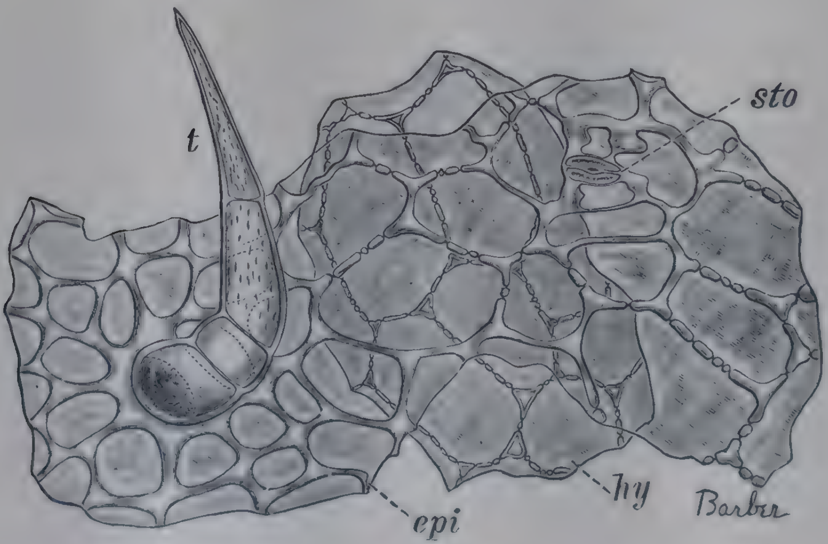

Fig. 144.

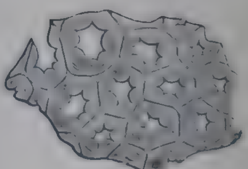

Fig. 145.

Fig. 144.—Muskmelon. Pericarp in surface view. *epi* epicarp with *t* hair and *sto* stoma; *hy* hypoderm. × 160. (K.B.W.)

Fig. 145.—Muskmelon. Epicarp in tangential section. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE.—Examination of netted melons of several varieties commonly grown in the temperate zone, as well as smooth cassaba and honey-dew melons, shows substantial agreement of structure of the inner fruit and the seed but marked differences in the epicarp.

Pericarp.—The marking of netted melons is due to cork cells (Fig. 143, *su*) which break through the epicarp similarly to the cells of lenticels. Between the reticulations the cells of the *epicarp* (Figs. 143 and 144, *epi*; Fig. 145) resemble those of the cucumber but have thicker walls, except in the grooves where they are thinner and porous, the lumen in cross section being flask-shaped. The numerous small *capitate hairs* of the immature fruit disappear on ripening, but the long (up to 375 μ), jointed, pointed, *warty hairs* (Fig. 144, *t*) persist at maturity in the depressions and grooves.

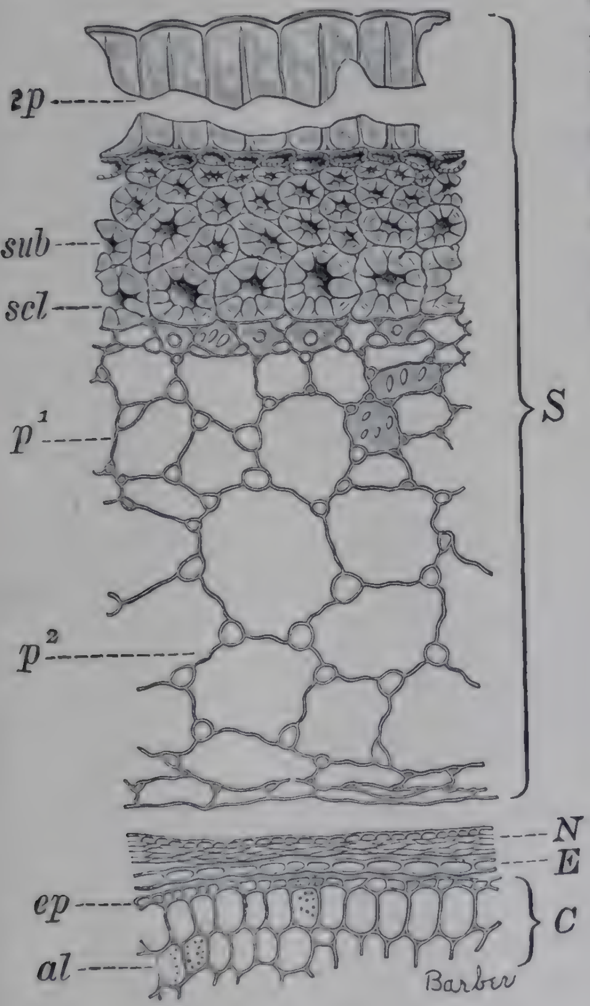

Fig. 146.

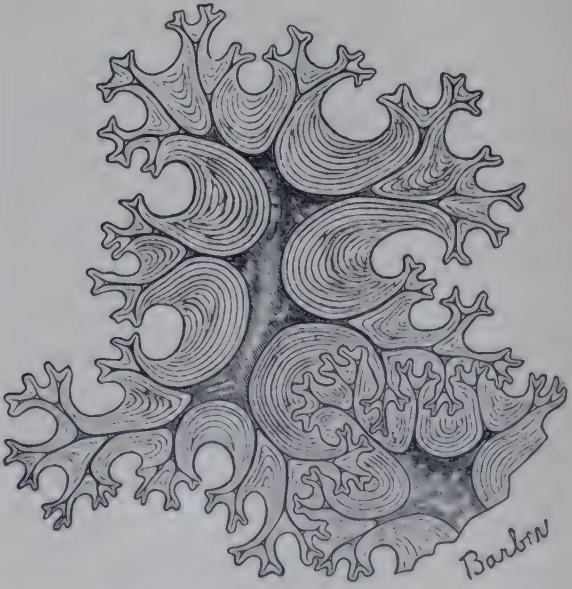

Fig. 147.

Fig. 146.—Muskmelon. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *sub* subepiderm, *scl* sclerenchyma cells, p^1 outer and p^2 inner spongy parenchyma. *N* perisperm. *E* endosperm. *C* cotyledon: *ep* epiderm, *al* aleurone grains. × 160. (K.B.W.)

Fig. 147.—Muskmelon. Isolated sclerenchyma cells (*scl* of Fig. 146). × 300. (K.B.W.)

The cells of the *hypoderm* (Figs. 143 and 144, *hy*) have somewhat thickened, porous walls. The remaining pericarp tissues differ little from the tissues of the cucumber except that the cells about the numerous fibro-vascular bundles of the inner mesocarp are disorganized as in the pumpkin.

Spermoderm (Fig. 146, *S*; Fig. 147).—The thickenings on the radial walls of the *outer epiderm* (*ep*) are narrow, not broad as in the cucumber; the *subepiderm* (*sub*) consists of several cell layers of sclerenchyma cells (a single layer in the cucumber); and the cells of the *spongy parenchyma* (p^1) are larger with slightly thickened, porous, sclerenchymatized walls. Otherwise the seed is like the cucumber seed.

CHIEF STRUCTURAL CHARACTERS.—Fruit globoidal or elongated, white, green, yellow, orange, or red, with or without reticulated surface. Seed yellow, like cucumber seed in form and size.

Reticulations due to cork cells; epicarp cells thick-walled except in the grooves, lumen flask-shaped; hairs warty, jointed. Outer epiderm of spermoderm with narrow, pointed thickenings; subepiderm of several layers of sclerenchyma cells. See also cucumber and table on p. 431.

CHEMICAL COMPOSITION.—Richardson[1] separated a sample of nutmeg (musk-) melon into five parts and analyzed all but the seeds which constituted 3.3 per cent of the whole. Bersch[2] separated 2 types of melon, *Persikaner* and *Zucker*, into edible part (49 and 46.5 per cent), rind (42.4 and 37.1 per cent), and seeds etc. (8.6 and 16.4 per cent), but analyzed only the edible part. Pratt and del Rosario[3] analyzed the edible part of 2 samples, one of which was the smooth-skinned *melón* with edible part 75, rind 15, and seeds 10 per cent, the other the rough-skinned *melón espagnol* with edible part 77, rind 13, and seeds 10 per cent. Youngken[4] followed the same plan in the examination of 2 sub-tropical varieties, cassaba and honey-dew, now extensively shipped throughout the United States. The samples contained respectively: edible part 50 and 45, rind 41 and 49, and seeds and placentæ 9 and 6 per cent. See table next page.

In the samples of melón and melón espagnol the sucrose obtained by copper reduction and by polarization was practically the same. The acidity calculated as citric was respectively 0.11 and 0.16 per cent, the alkalinity of the ash 52 and 50 cc. tenth normal acid per 100 grams of material.

Changes in Composition During Ripening and Storage.—Chace, Church, and Denny[5] studied California cantaloupes with the view of devising tests for determining when the fruit is in the proper condition for picking. A summary of the solids and sucrose in the juice of one

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[1] U. S. Dept. Agr. Rep. 1883, p. 236.

[2] Landw. Vers.-Stat. 1896, **46**, 473.

[3] Philippine J. Sci. 1913, **8**, A, 59.

[4] Am. J. Pharm. 1921, **93**, 104.

[5] U. S. Dept. Agr. 1924, Bul. **1250**.

COMPOSITION OF MUSKMELON AND ITS PARTS

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%
Richardson:								
Nutmeg								
Marc of edible part (4%)	76.44	1.36	0.18	17.40	....	....	2.13	1.49
Juice of edible part (46.3%)	90.53	0.50	....	8.41*	....	....	0.00	0.56
Interior juice (5.4%)	92.61	0.91	....	5.47*	....	....	0.00	1.01
Rind (40.5%)	91.15	0.62	0.50	6.17	....	....	0.88	0.68
Bersch:								
Persikaner								
Edible part (49%)	95.90	0.48	0.08	2.84	2.70	....	0.35	0.35
Whole fruit	93.87	1.27	0.81	2.12	1.85	....	1.32	0.61
Zucker								
Edible part (46.5%)	95.15	0.65	0.08	3.45	3.43	....	0.33	0.34
Whole fruit	92.85	1.60	0.48	3.52	2.60	....	1.06	0.49
P. and del R.:								
Melón								
Edible part (75%)	94.8	0.24	....	.....	2.39	0.37	....	0.52
Melón espagnol								
Edible part (77%)	96.0	0.80	....	.....	1.24	0.60	....	0.50
Youngken:								
Cassaba								
Edible part (50%)	89.05	1.21	0.00	8.40	1.87	0.84†	0.54	0.80
Honey-dew								
Edible part (45%)	90.52	0.51	0.00	8.09	2.05	1.89†	0.36	0.52

* Includes fat. † Calculated from increase in reducing power after inversion.

variety (Turlock) at different stages of development during 1916 follows:

	Solids			Sucrose		
	Min.	Max.	Aver.	Min.	Max.	Aver.
	%	%	%	%	%	%
Field ripe	10.0	13.1	**11.6**	2.96	6.37	**4.94**
Full slip*	10.5	13.3	**11.9**	3.77	6.47	**5.35**
Half slip*	10.2	13.5	**11.9**	3.02	7.20	**5.10**
Immature	7.1	11.4	**9.5**	1.21	4.47	**2.64**

* These designations refer to the degree of separation from stem.

The readings on the immersion refractometer and on the Brix spindle, also the percentages of sucrose, obtained on the juice of the Turlock cantaloupe of different degrees of marketability during 1920 are summarized below:

	Refraction			Brix			Sucrose		
	Min.	Max.	Aver.	Min.	Max.	Aver.	Min.	Max.	Aver.
							%	%	%
High quality....	50.9	69.4	**60.5**	9.0	13.5	**11.6**	4.48	7.78	**6.12**
Satisfactory....	46.2	67.2	**57.8**	8.0	12.8	**11.0**	3.25	7.51	**5.39**
Doubtful.......	40.8	56.8	**49.9**	7.1	10.7	**9.1**	1.99	4.46	**3.55**
Unmarketable...	34.6	55.4	**45.0**	5.1	10.9	**7.7**	0.30	3.80	**1.77**

The authors found that the seeds of melons of proper ripeness contain less than 0.5 per cent of starch, which diminished during storage. They further state that the melons gain in flavor but not in sweetness after picking, although during storage and shipment at low temperatures the change is slight. After softening at ordinary temperature there is a slight loss of sucrose.

Rosa,[1] in experiments with cantaloupes, honey-dews, and cassabas, notes, in addition to the progressive increase in the percentages of solids and total sugar during ripening, a decrease in the percentage of invert sugar due to respiration and conversion into sucrose and an increase in the percentage of sucrose more than offsetting the loss of invert sugar. Protopectin decreases owing to the disintegration of the middle lamella, while pectin remains nearly constant. In melons picked while immature, invert sugar changes progressively to sucrose during storage at ordinary temperatures, but there is little increase in total sugar and finally an actual loss due to respiration. The fruit becomes soft and mellow but does not attain the sweetness and flavor of the fruit that is picked when mature. Ethylene gas hastens the change from invert sugar to sucrose and the softening of the tissues but does not increase the content of sugar.

Proteins.—From the dry defatted seeds of the muskmelon Jones and Gersdorff[1] extracted with 2 per cent salt solution at 60° C. a *globulin* which on cooling separated as octahedral crystals. By extraction with 0.5 per cent sodium hydroxide solution they isolated a *glutelin*. The yield of the two proteins was 28.21 and 5.78 per cent respectively.

---

[1] Hilgardia 1928, **3**, 421.

Ultimate Composition.—The above-named authors give the following results:

	Globulin	Glutelin
	%	%
Carbon	52.65	55.20
Hydrogen	6.67	7.02
Nitrogen	18.41	16.28
Sulphur	1.13	0.90
Oxygen	21.14	20.60
	100.00	100.00

Amino Acids of Muskmelon Proteins.—The following results are partly by Van Slyke's method as given in Jones and Gersdorff's first paper[1] and partly from a later paper[2] giving revised figures for cystine and tryptophane:

	Globulin	Glutelin
	%	%
Cystine	1.30	1.11
Tryptophane	2.77	3.17
Arginine	16.26	12.42
Lysine	3.29	4.59
Histidine	4.22	2.72

Fatty Oil of Seed.—The *Physical and Chemical Values* of cold-pressed oil from the seeds of the cantaloupe (muskmelon), as determined by Baughman, Brauns, and Jamieson,[3] are specific gravity 25°/25° 0.9210; refractive index at 20° C. 1.4725 (at 25° C. 1.4707); saponification number 192.3; iodine number (Hanus) 125.9; Reichert-Meissl number 0.33; Polenske number 0.26; acetyl number 15.8; acid number 0.43; soluble acids, calculated as butyric, 0.4 per cent; insoluble acids 94 per cent; unsaturated acids, determined 79.2 per cent (iodine number 151.8), corrected 80.2 per cent; saturated acids, determined 15.3 per cent (iodine number 10.0), corrected 14.3 per cent; and unsaponifiable matter 1.1 per cent.

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[1] J. Biol. Chem. 1923, **56**, 79.

[2] Ibid. 1924, **62**, 183.

[3] J. Am. Chem. Soc. 1920, **42**, 2398.

The *Composition*, as calculated by the above-named authors, is as follows:

	%
Glycerides of:	
Stearic acid	4.5
Palmitic acid	10.2
Myristic acid	0.3
Oleic acid	27.2
Linolic acid	56.6
Unsaponifiable matter	1.1
	99.9

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan [1] reports 1.55 per cent, dry basis.

Enzymes.—Hou and Chen [2] call attention to an ereptase-like enzyme in the fruit flesh.

Minor Mineral Constituents. *Iron.*—Cantaloupe 5.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Aluminum.—Cantaloupe 7.7 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[4]

Copper.—Cantaloupe 0.6, Honey-dew melon 0.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[5]

Zinc.—Edible portion 0.9 mg. per kilo, fresh basis (Bertrand and Benzon).[6]

WATERMELON

Citrullus vulgaris Schrad.

Fr. Melon d'eau. Sp. Zandia. It. Cocomero. Ger. Wassermelone.

Explorers state that in central and southern Africa the watermelon is an important food of man and larger mammals. There are bitter and sweet natural varieties, the latter having been much improved by cultivation.

The citron melon is a variety with hard flesh, the rind of which like that of the true watermelon is used for preserves.

MACROSCOPIC STRUCTURE.—The small *flowers* with five-lobed corolla characterize this species as well as the cucumber and muskmelon.

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[1] Philippine Agr. 1932, **21**, 53.

[2] Chinese J. Physiol. 1927, **1**, 33.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Am. J. Physiol. 1929, **90**, 72.

[5] J. Biol. Chem. 1929, **82**, 465.

[6] Bul. soc. hyg. aliment. 1928, **16**, 457.

Unlike the muskmelon the *fruit* is solid. In form it is usually large, elongated, with a smooth green or green and white mottled outer surface. The outer rind is hard and white, inedible raw but useful for preserves, passing into the central edible portion which is crisp and juicy, of a red, pink, or yellow color. Embedded in the edible flesh are the white, brown, black, or mottled, lustrous or slightly roughened, marginless, flat, rather thick *seeds*.

MICROSCOPIC STRUCTURE. Pericarp (Figs. 148 and 149).—Jointed *hairs* occur on the ovary but disappear soon after fertilization, leaving only the scars on the mature fruit. The layers are (1) *epicarp* (*epi*) of cells up to 35 μ high, often broader than high, with thickened outer and radial walls, and thin-walled stomata (*sto*), (2) *hypoderm* (*hy*), several cells thick, of small, rounded, porous cells containing chlorophyl grains, (3) *outer mesocarp* consisting of a zone of porous sclerenchyma cells (*st*), interrupted by parenchyma (*x*), passing into (4) *middle mesocarp* (*mes*) of larger porous cells, (5) *inner mesocarp* of glistening, thin-walled cells so large (often 1.25 mm.) as to be visible to the naked eye, and (6) *endocarp* of small, thin-walled, elongated cells.

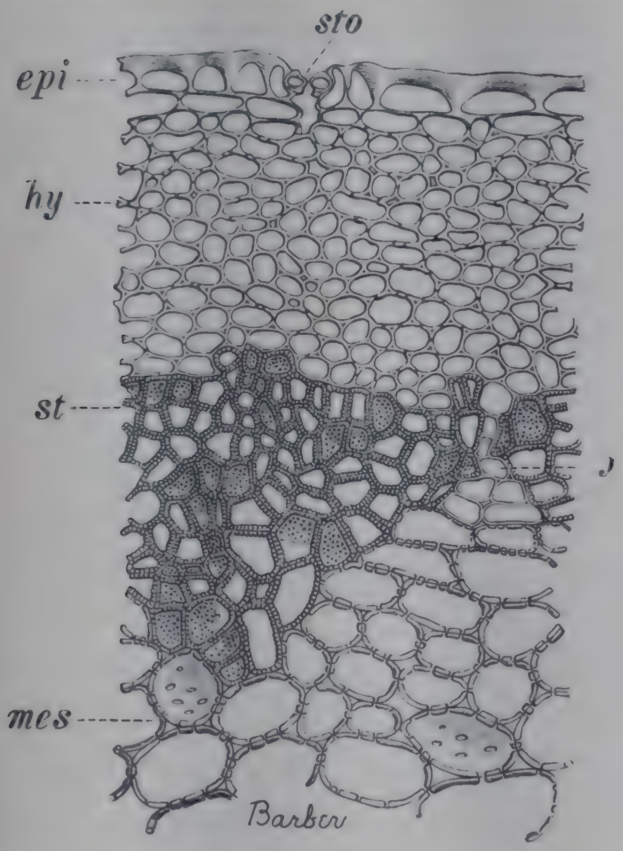

FIG. 148.

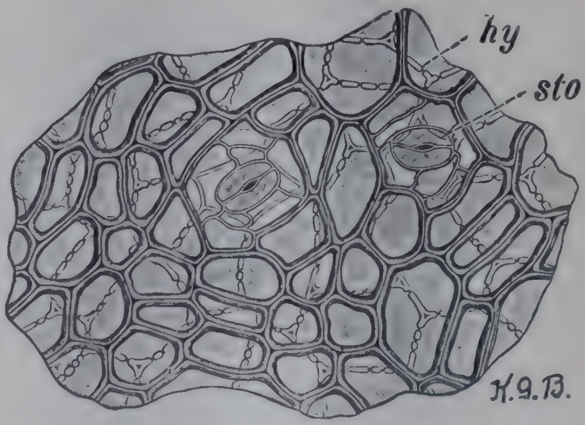

FIG. 149.

FIG. 148.—Watermelon. Outer pericarp in cross section. *epi* epicarp with *sto* stoma; *hy* hypoderm; *st* stone cells of outer mesocarp with *x* parenchyma cells; *mes* middle mesocarp. × 160. (K.B.W.)

FIG. 149.—Watermelon. Pericarp in surface view. Epicarp with *sto* stoma. *hy* hypoderm. × 160. (K.B.W.)

Fibro-vascular bundles, *sieve tubes*, and *latex tubes* are distributed throughout the mesocarp.

Spermoderm (Fig. 150, *S*).—The tissues are (1) *outer epiderm* (*ep*) of palisade cells up to 400 μ high, with a sclerenchymatized rod-like, pointed, occasionally forked thickening on each radial wall, a much-thickened cuticle (35 μ), and contents of the color of the seed; (2) *subepiderm* (*sub*) of thick-walled, porous, sclerenchyma cells, varying from small isodiametric forms in the outer layers to large irregular, often radially elongated cells, and finally to small isodiametric cells with walls so thick as nearly to obliterate the lumen; (3) *sclerenchyma cells* (*scl*) not markedly elongated in any direction; (4) sclerenchymatized, porous *spongy parenchyma* (p^1); (5) *simple parenchyma* (p^2); and (6) *inner epiderm* of small, thin-walled cells.

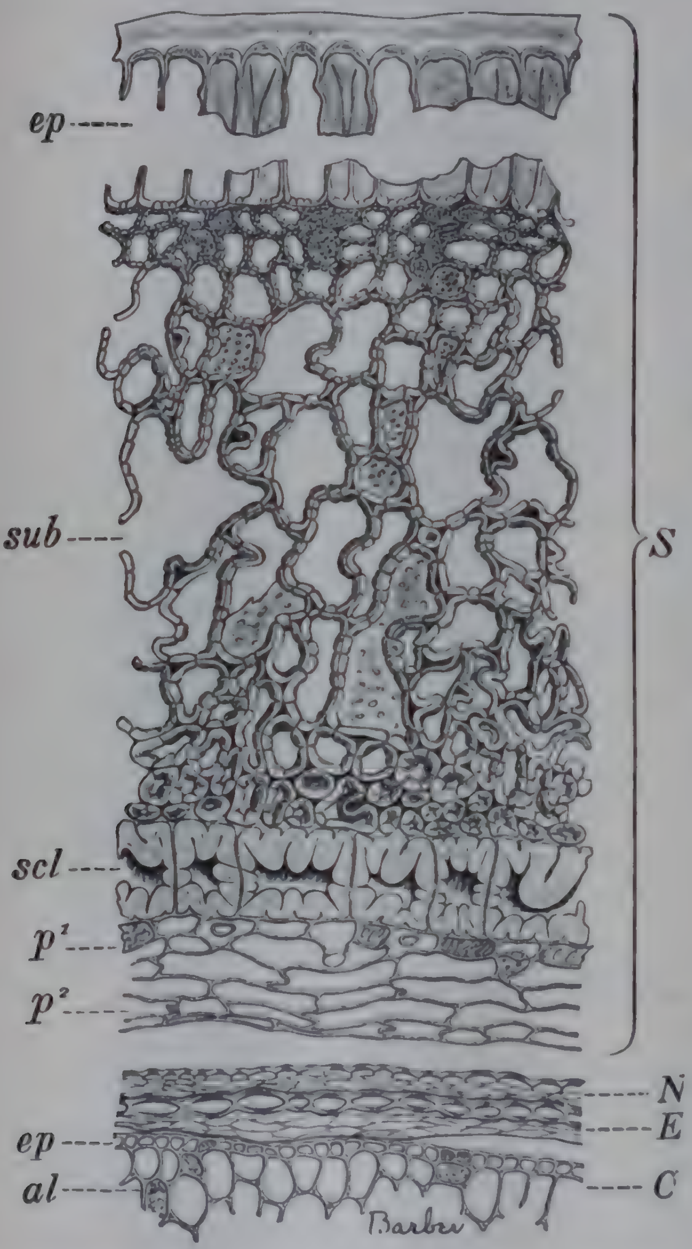

FIG. 150.—Watermelon. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *sub* subepiderm, *scl* sclerenchyma cells, p^1 outer and p^2 inner parenchyma. *N* perisperm. *E* endosperm. *C* cotyledon: *ep* epiderm, *al* aleurone grains. × 160. (K.B.W.)

Perisperm (Fig. 150, *N*).—Of cucurbitaceous type.

Endosperm (Fig. 150, *E*).—A single *aleurone layer* and a thin-walled tissue several cells thick.

Cotyledons (Fig. 150, *C*).—Of usual type.

CHIEF STRUCTURAL CHARACTERS.—Fruit large, usually elongated, smooth, dark green or mottled, solid with white rind and red, pink, or yellow core. Seeds black, brown, or white, marginless, rather thick.

Epicarp cells low with thick outer and radial walls; hypoderm of several cell layers; outer mesocarp of porous sclerenchyma cells, interrupted by parenchyma; middle mesocarp of larger porous cells, inner mesocarp of huge (1.25 mm.) glistening cells. Spermoderm with thick cuticle; outer epiderm with single rod-like thickenings on radial walls; subepiderm a thick layer with sclerenchymatized walls; cells of sclerenchyma layer nearly isodiametric. See also table p. 431.

CHEMICAL COMPOSITION.—Richardson [1] and Nardini [2] report separate analyses of the fruit, pulp, rind, and seeds. The pulp and juice together represent the edible portion, that is the part eaten out of hand, and not including the rind which is edible only after preserving and the seeds which like pumpkin seeds have sweet and nutritious kernels. Bersch [3] analyzed separately the whole fruit and the edible portion forming 60.4 per cent of the whole fruit. The inedible portion consisted of rind 35.2 and seeds etc. 4.4 per cent. Pratt and del Rosario [4] analyzed the edible portion of the fruit containing edible part 51, rind 45, and seeds 4 per cent. Incidental to the examination of the oil noted below,[5] analyses were made of the seed cake and calculated to the fat content of 7 per cent. Kondo and Hayashi,[6] in 5 samples representing 4 varieties grown in Japan, separated the edible portion (50 to 78, aver. **64** per cent of the whole fruit) and expressed the juice (89 to 97, aver. **92** per cent of the edible portion). The juice was strained through a cloth but evidently contained some matter in suspension as shown by the results on crude fiber. See table next page.

The soluble solids, as determined by Tucker,[7] increase from without inward, being in the green tissues beneath the rind 4.1 to 6.8 per cent, in the outer red tissues 9 to 10 per cent, and in the tissues about the seeds and in the core 11 to 15 per cent.

Changes in Composition During Ripening and Storage.—Rosa found that the same general changes take place in the watermelon as in the muskmelon (which see). See also Carbohydrates.

Amino Acids.—Wada [8] found in watermelon juice, after successive removal of substances precipitated by lead subacetate and by phosphotungstic acid after treatment with Neuberg's reagent, an amino acid, *citrulline*, with the following formula: $H_2N\cdot CONHCH_2\cdot CH_2\cdot CH_2\cdot CH(NH_2)COOH$. In a sealed tube it decomposes at 205 to 206° C.

Fatty Oil of Seed.—Power and Salway [9] examined the oil obtained from the seeds of American watermelons and studied other constituents of the seeds as noted below. A report on the characters of the

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[1] U. S. Dept. Agr. Rep. 1883, p. 236.

[2] Staz. sper. agr. ital. 1890, **18**, 448.

[3] Landw. Vers.-Stat. 1896, **46**, 473.

[4] Philippine J. Sci. 1913, **8**, A, 59.

[5] Bul. Imp. Inst. 1925, **23**, 149.

[6] Mem. Col. Agr. Kyoto Imp. Univ. 1928, No. 6, 55.

[7] Plant Physiol. 1934, **9**, 181.

[8] Proc. Imp. Acad. Japan, 1930, **6**, 15.

[9] J. Am. Chem. Soc. 1910, **32**, 360.

COMPOSITION OF WATERMELON AND ITS PARTS

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%
Richardson:								
Pulp (6.9%)	91.87	0.89	0.72	5.64	....	....	0.55	0.33
Juice (35.1%)	93.05	0.12	....	6.63*	....	....	....	0.20
Rind (55.8%)	89.97	1.43	0.36	5.59	....	....	1.41	1.24
Seeds (2.2%)	48.37	8.01	3.63	26.16	....	....	12.43	1.34
Nardini:								
Pulp (3.5%)	89.65	1.33	0.02	7.42	0.87†	....	1.32	0.26
Juice (63.1%)	93.62	0.21	0.01	5.99	4.95†	0.77	....	0.17
Rind (29.6%)	92.00	0.91	0.30	4.48	0.95†	....	1.65	0.66
Seeds (3.8%)	49.63	10.38	12.43	11.53	....	....	14.68	1.35
Whole fruit	91.35	0.83	0.56	5.81	3.91†	....	1.09	0.36
Bersch:								
Edible part (60.4%)	93.69	0.61	0.07	1.07	4.21	....	0.12	0.23
Whole fruit	93.44	0.90	0.45	1.43	2.45	....	1.01	0.32
P. and del R.:								
Edible part (51%)	91.30	0.60	....	....‡	5.73	1.25	....	0.18§
Bul. Imp. Inst.:								
Seed cake								
Min.	8.6	28.2	7.0	8.3	....	....	12.2	3.9
Max.	10.1	58.8	7.0	14.3	....	....	39.2	4.9
K. and H.:								
Juice‖								
Min.	88.87	0.22	0.02¶	....	3.92	0.54	0.07¶	0.24
Max.	93.43	0.56	0.06¶	....	5.36	3.76	0.08¶	0.34
Aver.	**91.80**	**0.44**	**0.04¶**	....	**4.50**	**2.71**	**0.07¶**	**0.29**

* Includes fat and fiber. † Invert sugar. ‡ Acid as citric 0.06%. § Alkalinity 17 cc. N/10 acid per 100 grams pulp. ‖ Pure protein 0.04 to 0.08, aver. **0.07**%; acidity 6.75 to 14.75, aver. **10.50** cc. N/10 alkali per 100 cc. juice; pH 4.99 to 5.89, aver. **5.08**. ¶ 3 samples.

VALUES OF WATERMELON SEED OIL

	Sp. gr. 15°/15°C.	Ref. index 40° C.	Sapon. No.	Iodine No.	Fatty acids, titer	Acid No.
					° C.	
Power and Salway	1.9265	......	191.8	121.1	....	3.9
Bul. Imp. Inst.						
Min.	1.9218	1.4645	190.1	113.1	29.2	1.3
Max.	1.9236	1.4670	195.1	124.3	35.3	17.8

oil from Kordofan Province appeared in 1916[1] and later a more complete report on the oil from seeds grown in various parts of Africa.[2]

The *Composition*, aside from unsaponifiable matter, as estimated by Power and Salway is:

	%
Glycerides of:	
Palmitic and stearic acids...	30
Oleic acid................	25
Linolic acid..............	45

Phytosterol.—A small amount of a phytosterol with the formula $C_{20}H_{34}O$ and the melting point 163 to 164° C. was isolated by Power and Salway.

Resin.—A new alcohol, *cucurbitol*, having the formula $C_{24}H_{40}O_4$ and melting at 260° C., was isolated by Power and Salway[3] from the resin separated from watermelon-seed cake. A relationship of this alcohol with grindelol from *Grindelia camporum* and ipurganol from jalap was indicated.

Carbohydrates.—Several authors have noted the presence of both reducing sugars and sucrose in the ripe fruit. Wiley[4] found in the meat juice and rind juice respectively: reducing sugars 4.33 and 2.47 per cent, sucrose 1.92 and 0.34 per cent. Sherwin and May[5] obtained the following figures for the juice: total solids, 12 samples, 7.76 to 11.76 per cent, reducing sugars by copper reduction, 14 samples, 4.31 to 5.97 grams per 100 cc.; sucrose, 18 samples, by copper reduction 2.01 and 0.89 grams per 100 cc., by polarization 0.72 to 1.64 per cent. The melons contained 41.2 to 51.5 per cent of juice, 7.1 to 12 per cent of pulp, and 41.4 to 50.9 per cent of rind.

Ivanov, Alexandrova, and Kudryasheva[6] believe that sugars are formed during ripening in the following order; dextrose, levulose, sucrose. When the levulose exceeds in amount the dextrose, sucrose begins to form and increases in amount to full ripeness. The amount of sucrose is a measure of quality and ripeness.

In experiments by Kondo and Hayashi[7] the base, middle, and end contained respectively: reducing sugars 5.13, 5.30, and 5.27 per cent; sucrose 2.81, 3.19, and 1.52 per cent. Levulose was found to be the predominating sugar.

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[1] Bul. Imp. Inst. **14**, 160.

[2] Ibid. 1925, **23**, 149.

[3] Loc. cit.

[4] U. S. Dept. Agr. Rep. 1886, p. 345.

[5] J. Ind. Eng. Chem. 1912, **4**, 585.

[6] Biochem. Z. 1929, **212**, 267.

[7] Loc. cit.

Enzymes.—*Sucrase* was detected by Kondo and Hayashi.[1]

Mineral Constituents.—The percentages of the common ingredients in the ash of the whole fruit as determined by Payne[2] and in the ash of the juice as determined by Nardini[3] and Kondo and Hayashi[4] appear in the following table:

Composition of Watermelon Ash

	Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Fruit:											
Payne....	0.33	61.18	4.31	5.54	6.74	0.48	....	10.25	4.41	2.15	4.94
Juice:											
Nardini..	....	51.98	5.75	8.73	2.42	0.71	1.75	3.82	17.31	3.33	4.03
K. and H.											
Yamato*	0.26	54.15	15.81	2.25	6.48	0.26	....	8.59	10.07	2.34	0.59
Kaho†..	0.30	51.03	14.93	2.20	7.66	0.42	....	12.49	7.47	2.17	2.16

* CO_2 in crude ash 12.97%. † CO_2 in crude ash 9.04%.

Minor Mineral Constituents. *Iron.*—Fruit 2.3 mg. per kilo, fresh basis (Peterson and Elvehjem).[5]

Aluminum.—Fruit 0.28 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause.[6]

Copper.—Seed coats, trace (Power and Salway).[7] Fruit 0.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson.)[8]

CASSABANANA

Sicana odorifera Naud.

Curuba is another name for this fruit. It is a native of South America and is grown throughout tropical America both as an ornamental and for food.

MACROSCOPIC STRUCTURE.—A specimen of the *fruit* furnished by Professor Cowles of the University of Puerto Rico was slender cylindrical, 70 cm. long, reddish yellow, and fragrant. The *seeds* were flattened, 1.5 cm. long, gray-brown, with dark brown margins.

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[1] Loc. cit.

[2] Georgia Dept. Agr. 1896, Bul. **32**, 29.

[3] Loc. cit.

[4] Loc. cit.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] Am. J. Physiol. 1929, **90**, 72.

[7] Loc. cit.

[8] J. Biol. Chem. 1929, **82**, 465.

MICROSCOPIC STRUCTURE. Pericarp.—The tissues are (1) *epicarp*, coated with wax, of thick-walled palisade cells up to 65 μ high, with bright yellow walls except about the stomata where the walls are thin and colorless; (2) *hypoderm* of small rounded cells, containing large bright yellow chromatophores, passing into (3) *outer mesocarp* of larger cells with mostly sclerenchymatized and porous, although not strongly thickened, walls; (4) *middle mesocarp* of still larger rounded parenchyma cells containing starch grains up to 27 μ, occurring singly (rounded) or in small aggregates (truncated); (5) *inner mesocarp* not well differentiated; and (6) *endocarp*, often adhering to the seed, of delicate elongated cells.

Fibro-vascular bundles, *sieve tubes*, and *latex tubes* are as in other cucurbits.

Spermoderm.—Five tissues are present: (1) *outer epiderm* of thin-walled, often collapsed cells, up to 250 μ high, with delicate rod-like, pointed thickenings; (2) *subepiderm* of sclerenchyma cells, about three cells thick, increasing in size inward, elongated and sinuous in surface view; (3) *sclerenchyma cells*, more or less oval in cross section; (4) collapsed thin-walled *parenchyma* with no evidence of differentiation; and (5) scarcely evident *inner parenchyma*.

Perisperm, Endosperm, and **Cotyledon** are of the group type.

CHIEF STRUCTURAL CHARACTERS.—Fruit slender, cylindrical, reddish yellow, fragrant. Seed flattened, 1.5 cm. long, gray-brown with brown margins.

Epicarp of palisade cells, 65 μ high, with bright yellow walls; hypoderm with yellow chromatophores; outer mesocarp sclerenchymatized, porous; middle mesocarp containing starch grains (27 μ). Outer epiderm of spermodern thin-walled, often collapsed; subepiderm about three cells thick, sclerenchymatized. See also table p. 431.

BALSAM PEAR

Momordica Charantia L.

Fr. Pomme de merveille.	Ger. Wunderapfel.
Jap. Tsuru-reishi.	Chin. Fu-qua.

American seedsmen catalog this plant as an ornamental, but in China and Japan, as well as in the Chinese Quarters of American cities, the immature fruit is sold as a vegetable and the seed masses of the ripe fruit as a condiment. It is a native of tropical Asia and Africa.

The English equivalent of the Chinese name *la-kwa* is " bitter squash." Further details are given by L. H. Bailey.[1]

MACROSCOPIC STRUCTURE.—At the edible immature stage the *fruit* (Fig. 151) is green, elongated, with longitudinal furrows and warts. At maturity it is yellow, splitting into three divisions, thus exposing the numerous seeds enclosed in bright red tissues stated to be edible aril, although examination of the green seed shows no adjoining tissues other than those of the inner pericarp. The case appears to be analogous to that of the pumpkin, the seeds of which at maturity have adhering endocarp. The ripe *seeds*, according to M. Kondo,[2] are brown, up to 1.5 cm. long, flattened, with scalloped edge and curious markings on the flat side.

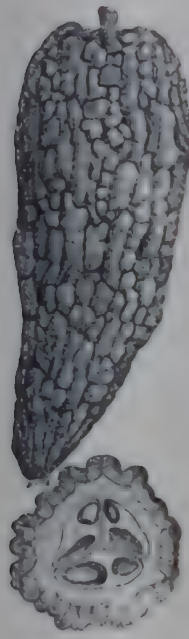

FIG. 151.—Balsam Pear. Immature fruit. × ¼. (A.L.W.)

MICROSCOPIC STRUCTURE. Pericarp.—The fruit at the edible stage shows the following details of structure: (1) *epicarp* of isodiametric, thin-walled cells with striated cuticle, stomata, and occasional small capitate hairs; (2) *hypoderm*, many cells thick, of rounded chlorophyl parenchyma; (3) *outer* and (4) *middle mesocarp* of spongy, often stellate, parenchyma; (5) *inner mesocarp* of small, rounded cells containing numerous monoclinic crystals; and (6) *endocarp* of polygonal cells and stomata.

Spermoderm.—In the green vegetable there is no marked differentiation of seed tissues. Kondo found four layers in the mature seed: (1) *outer epiderm* of palisade cells up to 60 μ with thick cuticle—no thickening on radial walls mentioned; (2) *subepiderm* of small, isodiametric cells, three to four cells thick; (3) *sclerenchyma layer*, several cells thick, of large, thick-walled, elongated cells; and (4) *parenchyma layer*, the outer cells spongy with small starch grains.

Perisperm, Endosperm, and **Cotyledon** are of usual type.

CHIEF STRUCTURAL CHARACTERS.—Fruit elongated, warty. Seeds flattened with scalloped edges and curious markings.

Crystals in innner mesocarp. At edible stage little differentiation in seed tissues. See also table p. 431.

CHEMICAL COMPOSITION.—Single analyses by Blasdale,[3] by Agcaoili,[4] and by Chung and Ripperton [5] follow:

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[1] Cornell Agr. Exp. Sta. 1894, Bul. **67**, 193.

[2] Ber. Ohara Inst. landw. Forsch. 1918, **1**, 309.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[4] Philippine J. Sci. 1916, **11**, 91.

[5] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

Composition of Balsam Pear

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Blasdale	93.61	1.18*	0.20	3.60	0.60	0.06	0.67	1.07	0.34
Agcaoili	92.73	1.26	0.03	5.18	....	....	....	0.12	0.68
C. and R.	89.20	1.49	0.12	5.71	....	....	....	1.68	1.80

* Pure protein 0.79%.

Fatty Oil of Seed.—No data are available on the oil from the seeds of *M. charantia* but figures are given by Corfield and Caird [1] for the oil expressed from the seeds of *M. cochinchinensis* which in several respects are radically different from those of other cucurbitaceous oils. The iodine number reported is only 23.4, while the refractive index (1.496 at 40° C.) and the melting point (28 to 32° C.) are high.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan [2] found 7.65 per cent, dry basis.

Colors.—Duggar [3] states that on ripening the red arils of *Momordica* follow the behavior of the tomato (which see), the chief pigment being *lycopersicin* (*lycopene*).

Mineral Constituents.—Chung and Ripperton [4] report: calcium 0.022, phosphorus 0.107, and iron 0.0024 per cent; alkalinity of ash (cc. normal acid per 100 grams of fresh vegetable) 22.9.

DISH-CLOTH GOURD

Luffa spp.

Fr. Éponge végétale. Ger. Luffaschwamm.

Species of the genus *Luffa* are known collectively as dish-cloth gourds or vegetable sponges because the dry fibrous interior of the mature fruit, after treatment, is used for washing and scrubbing. L. H. Bailey [5] states that two species (*L. acutangula* Roxbg., Chinese *sing-kwa*, and *L. cylindrica* Roem. = *Momordica cylindrica* L., Chinese *sua-kwa*) are cultivated as garden vegetables throughout the tropics,

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[1] Pharm. J. 1920, **104**, 43.

[2] Philippine Agr. 1932, **21**, 53.

[3] Washington Univ. Studies 1913, **1**, 22.

[4] Loc. cit.

[5] Cornell Agr. Exp. Sta. 1894, Bul. **67**, 195; Stand. Cyclo. Hort., New York, 1922, p. 1921.

China, and Japan to be cooked like squash while still immature. The former species is commonly grown in Chinese gardens about New York, and the vegetable is sold in New York Chinatown where the fresh material examined was obtained. Mature seeds of only *L. cylindrica* were obtainable.

MACROSCOPIC STRUCTURE.—The *fruit* is green, elongated, pear-shaped, and curved, resembling a crookneck squash, the species differing chiefly in the presence (*L. acutangula*) or absence (*L. cylindrica*) of ten prominent longitudinal ridges (Fig. 152). The *seeds* of both species are flattened, up to 12 mm. long, rather thick, and commonly black.

MICROSCOPIC STRUCTURE. Pericarp.—A cross section of the immature fruit of *L. acutangula* shows five tissues: (1) *epicarp* of rounded, polygonal, thick-walled cells with striated cuticle, numerous stomata, and two kinds of scattered hairs; (2) *hypoderm*, a few cells thick, of small rounded cells containing chlorophyl grains; (3) *outer mesocarp* of groups of rounded parenchyma cells alternating with groups of porous, sclerenchyma cells; (4) *inner mesocarp* of thin-walled, loose tissue with latex tubes, isolated sieve tubes, and very numerous large fibro-vascular bundles; and (5) *endocarp* of thin-walled, elongated cells often side by side in groups.

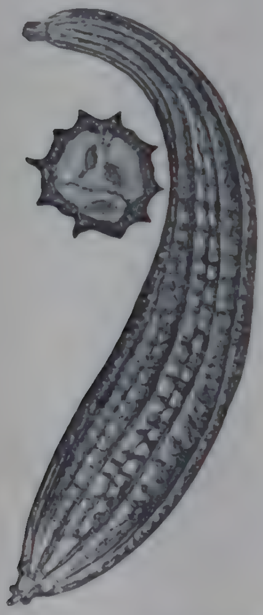

FIG. 152.—Dish-Cloth Gourd. Immature fruit. × ¼. (A.L.W.)

Both kinds of *hairs* are small and multicellular; one is jointed and striated, the other has a multicellular head on a scarcely evident stalk.

The *fibro-vascular bundles* consist largely of strong fibers with only a few small vessels.

Spermoderm.—At the edible stage only thin-walled, characterless tissues are present. Mature seeds of *L. cylindrica* (Fig. 153, *S*) show four layers: (1) *outer epiderm* (*ep*) of palisade cells of uneven height (30 to 60 μ) with a single rod-like thickening on each radial wall joined to both outer and inner walls, and dark contents; (2) *subepiderm* (*sub*) of one to five layers of reticulated or porous thin-walled cells and a single layer of small tangentially elongated, thick-walled cells; (3) *sclerenchyma cells* (*scl*), radially elongated to 235 μ, with narrow lumen and branched outer and inner walls; and (4) thin-walled, stellate, *spongy parenchyma* (*p*).

A tangential section of the outer cells of the *subepiderm* shows peculiar looping of the radial walls, each loop being closed.

Perisperm (Fig. 153, *N*), **Endosperm** (*E*), and **Cotyledon** (*C*) lack distinctive features.

Chief Structural Characters.—Fruit green, crook-necked, with or without ribs. Seeds flattened, black.

At immature edible stage epicarp with hairs, seeds characterless. See also table p. 431.

CHEMICAL COMPOSITION.—The fruit of *L. acutangula* has been analyzed by Blasdale[1] and by Chung and Ripperton[2] and the fruit of *L. cylindrica* by Blasdale,[1] by Agcaoili,[3] and by Sherman and Wang.[4] Blasdale's samples came from the Chinese Quarters of San Francisco, Chung and Ripperton's from Hawaii, and Sherman and Wang's from Peiping. *Seegua* is given as the Chinese name of the Hawaiian sample on the authority of Prof. Shao Chang Lee of the University of Hawaii, and *hechima* as the Japanese name on the authority of G. Kawahara, seedsman. See page 470.

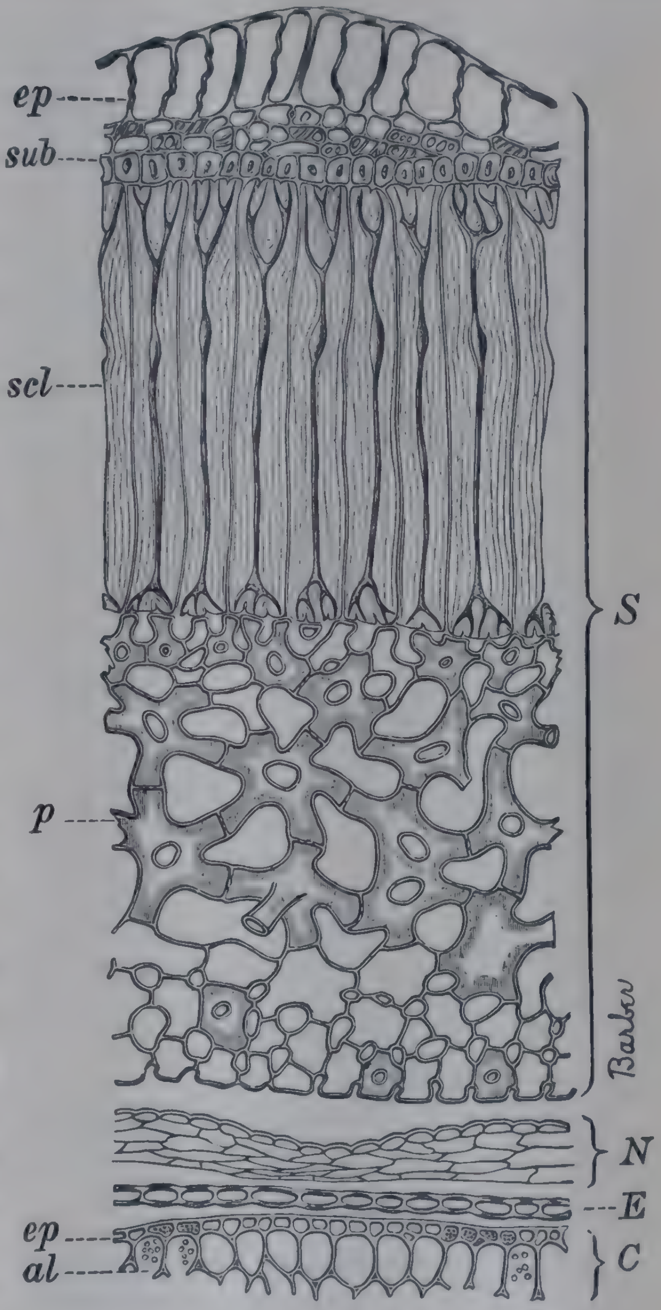

Fig. 153.—Dish-Cloth Gourd. Seed in cross section. *S* spermoderm: *ep* outer epiderm, *sub* subepiderm, *scl* sclerenchyma cells, *p* stellate parenchyma. *N* perisperm. *E* endosperm. *C* cotyledon: *ep* epiderm, *al* aleurone grains. × 160. (K.B.W.)

Fatty Oil of Seed.—Hooper[5] gives the following figures for the slowly drying oil from the seeds of *L. ægyptica* grown in India: specific gravity at 15° C. 0.921 to 0.926, saponification number 193.0 to 195.8, Reichert-Meissl number 0.49 to 0.52, fatty acids 93.5 to 94.2 per cent, acid number 33.0 to 36.4, fatty acids, titer 34 to 35° C.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[3] Philippine J. Sci. 1916, **11**, 91.

[4] Ibid. 1929, **38**, A, 69.

[5] J. Soc. Chem. Ind. 1908, **27**, 906.

Composition of Dish-Cloth Gourd

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
L. acutangula:									
Blasdale....	94.90	0.68*	0.24	3.03	1.57	0.10	0.36	0.72	0.43
C. and R...	95.91	0.77	0.05	2.22	....	....	....	0.63	0.42
L. cylindrica:.									
Blasdale....	94.66	0.51†	0.19	3.77	2.15	0.12	1.04	0.46	0.41
Agaoili.....	94.58	0.63	0.13	4.25	....	....	....	0.13	0.28
S. and W...	93.16	1.35	0.15	3.98	....	....	....	0.66	0.70

* Pure protein 0.54%. † Pure protein 0.38%.

On the oil of *L. acutangula*, Kesava-Menon[1] obtained the following values: refractive index at 25° C. 1.4741, saponification number 229.2, and iodine number 40.1, none of which figures is in accord with others given herewith or with those usually reported for common cucurbitaceous oils.

Ivanov and Troitzkii[2] report the following results for the seeds of *L. acutangula* and *L. cylindrica* grown in Russia and the oil obtained therefrom: shell 53.4 and 48.8 per cent, kernel 46.6 and 51.2 per cent, oil in kernel 40.30 and 42.51 per cent, iodine number 114.8 and 113.4, and acid number 7.92 and 7.36.

Phosphorus-Organic Compounds. *Phytin.*—In the fruit of *L. acutangula* and *L. cylindrica*, Bagaoisan[3] found respectively 7.84 and 4.66 per cent, dry basis.

Mineral Constituents.—Chung and Ripperton in the sample of fruit of *L. acutangula* noted above found calcium 0.005 and phosphorus 0.020 per cent. The alkalinity of the ash (cc. normal acid per 100 grams of fresh vegetable) was 3.8.

WAX GOURD

Benincasa hispida Cogn. = *B. cerifera* Savi.

Jap. Togwa. Chin. Dung-kwa.

This fruit is also known as white gourd melon, as Chinese preserving melon and, less appropriately since it is not eaten raw, as Chinese watermelon. In the Philippines the common name is *condol*. It is much used in the Orient both immature and fully ripe for preserving and is commonly sold in Chinese Quarters of American cities. Some American seedsmen catalog the seed.

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[1] J. Soc. Chem. Ind. 1910, **29**, 1428.

[2] Masl. Zhir. Delo. 1928, No. 1, p. 30.

[3] Philippine Agr. 1932, **21**, 53.

There appears to be confusion in the nomenclature, the seeds being of two types. The first is represented by one of two samples kindly furnished by Homer C. Skeels of the U. S. Department of Agriculture, Bureau of Plant Industry, and the seeds from the fruit bought in New York Chinatown as well as the seeds described by L. H. Bailey[1] and Fickel.[2] To the second type belongs the second sample from Skeels, as well as a sample from the seedsmen J. M. Thorburn and Co., New York, both of which conform to the description of M. Kondo.[3]

MACROSCOPIC STRUCTURE.—The ripe *fruit* of the first type resembles a watermelon in outward appearance, being elongated, green mottled with white. It, however, has a wax coating. Internally it differs from the watermelon in having white flesh throughout like the citron melon. When young the fruit (Fig. 154) is densely hairy, but the hairs largely disappear on ripening. The *seeds* of the first type mentioned above are thick, smooth, rounded, up to 13 mm. long, without sharp edge or margin; those of the second type are flattened and margined.

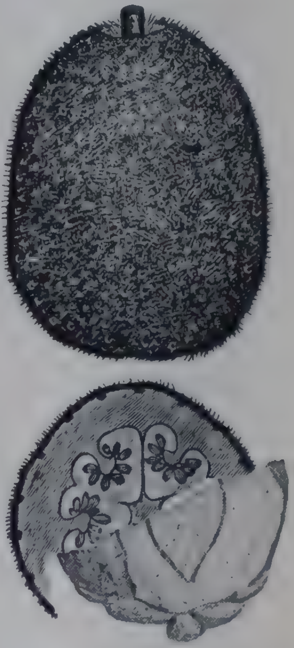

Fig. 155.—Chayote. Gourd. showing sin- fruit. ended seed (A.L.W. cotyle- minute

MICROSCOPIC STRUCTURE. Pericarp.—Except for the presence of the wax coating of the *epicarp* the structure of the mature fruit is very similar to that of the common watermelon. On the immature fruit, however, there is a dense covering of hairs which are long (up to 0.5 cm.), jointed, pointed, stiff, and more or less warty.

Spermoderm.—Seeds of the first type show four distinct tissues: (1) *outer epiderm* of thin-walled cells with little if any radial elongation and without thickenings on the radial walls, (2) *subepiderm* of thick-walled, porous sclerenchyma cells, many cells thick, of various shapes, often tangentially elongated in the middle layers, (3) *sclerenchyma cells* usually forming a double layer, and (4) *compressed parenchyma*, spongy in the outer part.

The absence of radial elongation and of thickenings of the *outer*

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[1] Cornell Agr. Exp. Sta. 1894, Bul. 67, 191.

[2] Inaug. Dis., Bot. Ztg. 1876.

[3] Ber. Ohara Inst. landw. Forsch. 1898, 1, 298.

epiderm and the frequent presence of tangential walls dividing the cells are characteristic.

In seeds of the second type the cells of the outer epiderm are radially elongated four to six times their breadth and have a slender rod on each radial wall the whole length of the cell, sometimes branching at the end.

Perisperm, Endosperm, and **Cotyledon** are of the usual type.

CHIEF STRUCTURAL CHARACTERS.—Fruit resembles common watermelon but with white flesh.

Pericarp similar to watermelon in structure except for waxy coating of epicarp and the numerous hairs of the immature fruit. Outer epidermal cells of spermoderm of two types: (1) not radially elongated and without thickenings on radial walls, and (2) greatly elongated and with rod-like thickenings. See also table p. 431.

CHEMICAL COMPOSITION.—Blasdale[1] analyzed the fruit as found on sale in San Francisco. It is not stated whether the sample was green or ripe or whether the seeds were removed previous to analysis. Pratt and Del Rosario,[2] Agcaoili,[3] and Chung and Ripperton[4] analyzed the edible portion, that is presumably the whole rind after removal of the seeds. Sherman and Wang[5] made a single analysis of the fruit from China.

COMPOSITION OF WAX GOURD

	Water	Protein	Fat	N-f. ext.	Acids as malic	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
..	96.24	0.50	0.16	2.18	....	0.90	0.07	0.31	0.57	0.35
R.	95.00*	0.69	....	....	0.07	2.09	0.54	....	....	0.40†
....	95.90	0.46	0.17	2.26	....	....	....	....	0.54	0.37
ature..	95.80	0.47	0.02	2.69	....	....	....	....	0.56	0.45
ature....	96.20	0.40	0.03	2.24	....	....	....	....	0.68	0.45
S. and W...	96.53	0.39	0.03	2.15	....	....	....	....	0.51	0.39

* Insoluble solids 2%. † Alkalinity 37 cc. $N/10$ acid per 100 grams pulp.

An analysis of the fruit by Yoshimura and Iwata[6] shows: water 97.10, protein 0.57, pure protein 0.19, fat 0.09, fiber 0.51, ash 0.38, total nitrogen 0.092, protein nitrogen 0.031, ammonia nitrogen 0.002, nitrogen in phosphotungstic acid precipitate 0.020, and nitrogen in other forms 0.039 per cent; adenine hydrochloride 3.3 and trigonelline hydrochloride 6.7 mg. per kilo.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. **68**.

[2] Philippine J. Sci. 1913, **8**, 59.

[3] Ibid. 1916, **11**, 91.

[4] Hawaii Agr. Exp. Sta. 1929, Bul. **60**.

[5] Philippine J. Sci. 1929, **38**, 69.

[6] J. Agr. Chem. Soc. Japan 1933, **9**, 1235.

Mineral Constituents.—Chung and Ripperton[1] found in the edible portion of the immature and mature fruit of the wax gourd respectively: calcium 0.011 and 0.015, phosphorus 0.025 and 0.021, and iron 0.0006 and 0.0024 per cent. In both cases they give 5.30 as the alkalinity of the ash expressed in terms of cubic centimeters of normal acid per 100 grams of fresh vegetable.

CHAYOTE

Sechium edule Swartz = *Chayota edulis* Jacq.

Publications of Cook[2] and Hoover[3] detail the history and characters of this plant. It is a native of tropical and sub-tropical America and has been cultivated since ancient times. The fruit and tubers were largely used in Mexico and Central America previous to the Spanish Conquest and today are as important there as the potato is farther north. It has been introduced by the Office of Seed and Plant Introduction, Bureau of Plant Industry, into the warmer regions of the United States and should prove a valuable vegetable especially since the fruit has good flavor, transports well, and keeps in storage for several months.

The vine is ornamental and also yields straw and fiber; the foliage is useful for forage, the young leaves and tips make good greens; the blanched shoots are a substitute for asparagus; the fruit is a Winter vegetable; the enormous (up to 2.5 kilos) tuber is a starchy food from which starch is prepared; and the ten nectaries make the flower valuable in honey production.

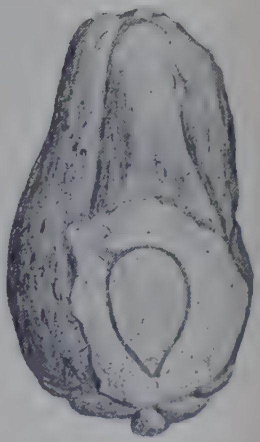

Fig. 155.—Chayote. Fruit showing single suspended seed with large cotyledon and minute radicle. × ¼. (A.L.W.)

Through the many years of cultivation many varieties have been developed, the most desirable fruit for the markets of the United States weighing 0.35 to 0.7 kilo, with smooth surface, light color, and minimum of fiber.

MACROSCOPIC STRUCTURE.—The *fruit* (Fig. 155) is green to white, roughly pear-shaped or round, smooth in the better grades, grooved and sometimes spiny in the poorer varieties. Unlike the other cucurbits described in this work, the fruit has but one seed which is suspended from the upper end of the cavity and entirely fills it. The *seed* is flattened and varies up to 5 cm. in length. Although the fruit stores well for several months, the seed without resting continues to grow and even before harvesting the cotyledons may protrude from the fruit without apparently impairing the flavor. The Indians pinch off the sprout before storing. As the spermoderm at no stage is hard, the seeds are not removed before cooking unless desired to eat separately.

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[1] Loc. cit.

[2] U. S. Dept. Agr., Div. Bot. 1901, Bul. **28**.

[3] U. S. Dept. Agr., 1923, Dept. Cir. **286**.

MICROSCOPIC STRUCTURE. Pericarp.—Four layers are present: (1) *epicarp* of polygonal cells, with somewhat thickened walls, numerous stomata, small capitate hairs, and emergences; (2) *hypoderm* of groups of polygonal, porous, sclerenchyma cells surrounded by tangentially elongated, fiber-like cells running in various directions; (3) *mesocarp* of thin-walled rounded parenchyma cells, containing rounded starch grains up to 10 μ, fibro-vascular bundles with numerous broad reticulated, spiral, and annular vessels, large sieve tubes, and latex tubes; and (4) *endocarp* of small, thin-walled cells enclosing the seed.

The *hairs*, occurring mostly in the grooves, have four-celled heads and long jointed stalks. The *emergences*, with dry, stiff, sclerenchyma elements, vary in size and number with the variety. The *fibers* of the hypoderm vary greatly in number, being fewest in the better grades. The *latex tubes* are not so conspicuous as the large, very refractive isolated *sieve tubes* which are evident with low power.

Spermoderm.—At the edible stage, only three layers are well differentiated: (1) *outer epiderm* of thin-walled cells, polygonal in surface view; (2) *subepiderm*, about two cells thick, of small thin-walled cells; and (3) *parenchyma* forming a broad band with large loosely arranged cells in the middle portion containing starch grains, and numerous raphe bundles.

The *starch grains*, up to 15 μ, are rounded, egg-shaped, or when in small aggregates truncated, with a distinct hilum but indistinct rings and polarization crosses.

Perisperm and **Endosperm** are much reduced.

The large **Cotyledons** consist of small cells filled with *starch grains* like those of the spermoderm but smaller.

CHIEF STRUCTURAL CHARACTERS.—Fruit greenish, smooth or spiny. Seed large, flattened, occurring singly (in other cucurbits described above seeds numerous).

Epicarp with hairs, mesocarp with small starch grains. Spermoderm of thin-walled cells, middle parenchyma with starch grains (in other cucurbits described herewith one or more spermoderm layers of thick-walled cells). Cotyledons large, packed with starch grains.

CHEMICAL COMPOSITION.—One analysis each of the fruit from Japan, where it is known as *hayato-uri*, by Yoshimura[1] and from the Philippines by Valenzuela and Wester[2] follow:

Composition of Chayote

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Yoshimura..	95.97	0.66	0.05	2.75	0.29	0.28
V. and W...	93.28	0.64	0.24	5.25	0.36	0.23

Of the total nitrogen of Yoshimura's sample, 59.99 per cent was in the form of true protein.

Nitrogenous Bases.—From 20 kilos there were isolated by Yoshimura[1] 0.7 gram of *arginine* as nitrate and 0.5 gram of *guanidine*. Traces of *adenine* and *choline* were present.

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[1] J. Biochem. Japan 1922, **1**, 347.

[2] Philippine J. Sci. 1930, **41**, 85.

PART II

FRUITS

PART II

FRUITS

The edible portion of fruits in most cases consists of the succulent pericarp (fruit coat), including, in berries, the seeds. In certain cases other organs associated with the fruit proper, because of their physical and chemical characters, are edible. For example, in the pomes the pericarp is consolidated with the receptacle to form the fruit flesh; in the strawberry the receptacle and that only is juicy, the pericarp being dry and meager; in the pomegranate the outer seed coat is enormously developed and contains a luscious juice; in the litchi and longan only the aril is edible; and in the cashew apple it is only the fleshy fruit stalk (peduncle) that is succulent and fruit-like.

The succulent leaf stalk of the garden rhubarb and the stem of angelica, the latter best known in the candied form, are fruit-like but are placed in the vegetable group for morphological reasons. Tomatoes and melons are classed with vegetables because the plants are garden annuals closely related to species that permit of no other classification.

Structure is further outlined in the introduction to Volume I.

Fruits are deficient in proteins and other nitrogenous substances, although the seeds may be rich in globulins. As a class they are succulent, saccharine, and acid. Some, such as the date, banana, and carob bean, are so saccharine as to mask any acid flavor, and others, such as the bilimbi and carambola, are so acid as to mask any sweetness. During ripening sucrose formed in the earlier stages tends to undergo inversion. The increase in sugars is commonly accompanied by a decrease in acids. Starch, which is more or less abundant in the unripe fruit (e.g., banana, apple), is converted into sugars during ripening. Numerous fruits are rich in pectin and adapted for making jelly. Apple pomace and citrus albedo are sources of commercial pectin (see Introduction).

The avocado is an exception among common fruits in that the pulp is oily; the seeds of fruits, however, are more often oily than starchy. Latex occurs in the sapodilla and certain other tropical fruits. The colors are chiefly anthocyanins, carotenoids, and flavones. The characteristic fruity flavor is due to ethers, aldehydes, alcohols, terpenes, or astringents, or else a mixture of these.

The fruit pulp, although acid, burns to an alkaline ash owing to the formation of carbonates from the acid salts.

FRUITS OF THE PALM FAMILY

(*Palmaceæ*)

Two succulent fruits, the date and the palm nut (a drupe), are classed with food products, the latter, however, being valuable chiefly because of the oil contained in both the pericarp and seed, is described in Volume I.

Both the ivory nut and the date contain reserve material in the seed in the form of thickened cell walls. Tannin bodies (*Inklusen*) have been noted only in the date. The sago palm and its relatives produce starch in the "trunk," and various species yield fibers and other technical products.

DATE

Phœnix dactylifera L.

Fr. Datte. Sp. Datil. It. Dattero. Ger. Dattel.

Dates are the principal food of the Arabs and their camels. The date palm has been grown in the region extending from Persia through northern Africa to the Canary Islands since prehistoric times and has not lost in importance through the ages. Because of the efforts of specialists in the Department of Agriculture, date culture has become an established industry in Arizona and southern California.

Among the requisites for the production of a remunerative crop are suitable varieties, careful pollination, a hot dry climate, and sufficient water at the roots. The proper conditions of intense heat above ground and moisture below are met in the oases of the Sahara where a tree may yield as many as 20 clusters and as much as 100 kilos of fruit. A moist atmosphere is fatal not only to production but also to the sun drying of the fruit.

The varieties are usually grouped according to the nature of the fruit as (1) " soft," that is rich in saccharine juice, to which class belong the dates shipped to Europe and America, and (2) " dry," the fruits of which, being hard, non-sticky, and of good keeping properties, are preferred by the Arabs. A third rather indefinite class includes those with abundant juice but with such low sugar content as to permit spoilage during drying by the sun's heat, thus necessitating consumption while fresh. Although the soft varieties are best suited to produce soft dates and the dry varieties dry dates, under certain conditions varieties of either class produce fruit with characters approaching those of the other. All varieties are diœcious and are commonly propagated by root suckers rather than seed. One male tree suffices for pollination of an orchard of a hundred trees, provided nature is assisted in distributing the pollen.

Dates, free from the stem (rachis), are commonly packed by the Arabs in boxes or grass mats and by Americans in various modern containers. The celebrated " deglet noor " dates of the Saraha are often attractively packed on the stem, one or more stems to the box. The color of the dried date depends partly on the color of the fresh fruit, which may be red or yellow or intermediate, and partly on the care taken in harvesting and drying.

Dates stuffed with nuts and rolled in sugar are prepared on a commercial scale and in the household. Various other kinds of confections contain dates.

MACROSCOPIC STRUCTURE.—The *flowers*, whether male or female, are produced on numerous branchlets forming a cluster enclosed in a spathe. Both kinds of flowers are small and on the plan of three. Three inconspicuous sepals, three fleshy petals, and six stamens are present in the male flower. In the female flower there are three carpels but if fertilized only one matures. Strangely enough, if not fertilized all three develop, albeit imperfectly and without seeds.

The *fruit* is a berry, not a drupe, although the hard stone which is the seed might be mistaken for endocarp. In extreme cases it reaches 7 cm. or over in length, but commonly is about half that length. It is more or less elongated, yellow or red, lustrous, and commonly has the small cup-shaped perianth attached at the base. The true endocarp is a tough, whitish coat with a silky luster closely pressed to the stone but not united with it.

A longitudinal groove runs along the ventral side of the *seed* (Fig. 156, I) while a round spot on the dorsal side marks the position of the minute embryo (II and III, *Em*) just beneath the surface. Except in the groove, the spermoderm (III, *S*) is reduced to a mere skin. The perisperm is still thinner. By far the greater part of the seed is horny endosperm (III, *E*), similar to that of the coffee bean and the ivory nut.

MICROSCOPIC STRUCTURE.—Braun [1] was the first to make a systematic study of the fruit tissues and describe the tannin bodies. Tichomirow [2] notes the presence of the tannin bodies. Hanausek [3] amplifies the work of the foregoing authors, dwelling on the tannin bodies (*Inklusen*) and the siliceous bodies accompanying the bundles.

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[1] Z. allg. oesterr. Apoth.-Ver. 1878, **16**, 341.

[2] Bot. Zentralb. 1885, **21**, 222.

[3] Pharm. Post 1910, **43**, 1041.

Moeller and other authors describe the structure of the seed (date stone), which has been used as a coffee substitute and adulterant.

Pericarp (Fig. 157, *F*; Fig. 158).—Eight layers or zones are differentiated: (1) *epicarp* (*epi*) of polygonal cells and stomata (*sto*); (2) *hypoderm* (*hy*) also of polygonal cells, somewhat flattened in cross section, with brown contents; (3) *stone cells* (*st*) forming a zone interrupted by parenchyma; (4) *outer mesocarp* (mes^1) of medium-sized, for the most part rounded, isodiametric, parenchyma cells; (5) *tannin cells* (*tan*), characterized by their large size and yellow-pink contents, forming a zone with smaller parenchyma cells; (6) *middle mesocarp* of parenchyma like that in the outer, accompanied by fibrovascular bundles, forming the bulk of the fruit tissue; (7) *inner mesocarp* (mes^2) of longitudinally elongated, somewhat spongy cells; and (8) *endocarp* (*end*) of narrow, longitudinally elongated cells some of which are sclerenchymatized and porous.

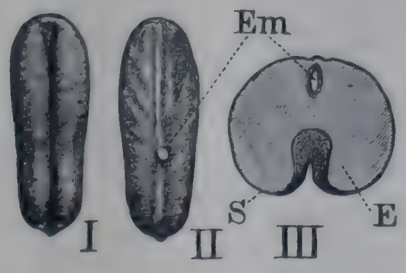

Fig. 156.

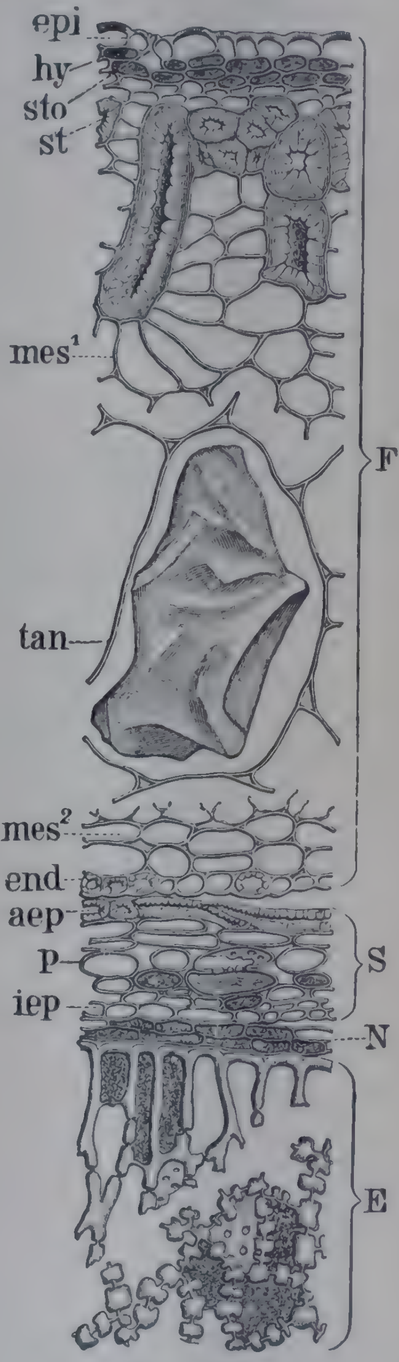

Fig. 157.

Fig. 156.—Date. Seed. I ventral side; II dorsal side. × 1. III cross section. *S* spermoderm; *E* endosperm; *Em* embroyo in cavity. × 2. (K.B.W.)

Fig. 157.—Date. Fruit and seed in cross section. *F* pericarp: *epi* epicarp with *sto* stoma, *hy* hypoderm, *st* stone cells, mes^1 outer mesocarp, *tan* tannin cell, mes^2 inner mesocarp, *end* endocarp. *S* spermoderm: *aep* outer epiderm, *p* parenchyma, *iep* inner epiderm. *N* perisperm. *E* endosperm. × 160. (K.B.W.)

Many of the *stone cells* have walls thicker than the lumens. They are either isodiametric or radially elongated, the neighboring parenchyma cells often being elongated and radiating from them.

Of special interest are the *tannin cells,* so called because of the irregular bodies contained in them which, like the similar bodies of the carob bean, give the tannin reaction (green) with ferric chloride. Iodine in potassium iodide colors them yellow-brown and safranin brilliant red. Hanausek adopts Tichomirow's term *Inklusen* or *Inklusionen* for the tannin bodies, neither of which words nor a translation seems suitable in English. The same author finds narrow elongated tannin cells in the inner mesocarp of green dates near or adjoining the endocarp, some of which, however, do not have homogeneous contents and others are empty. He also finds starch in the neighboring parenchyma. In dried dates examined by us, neither tannin cells nor starch were evident in this region.

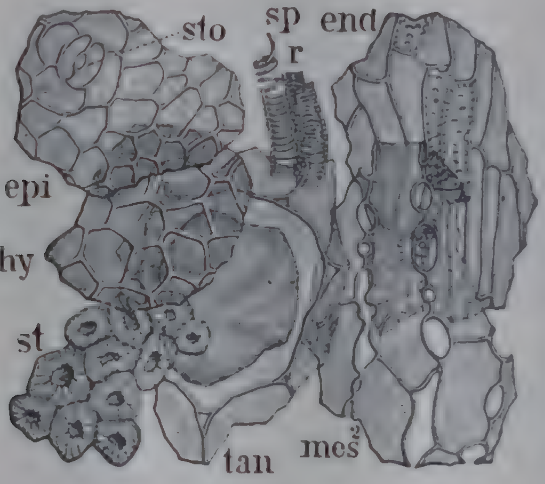

Fig. 158.

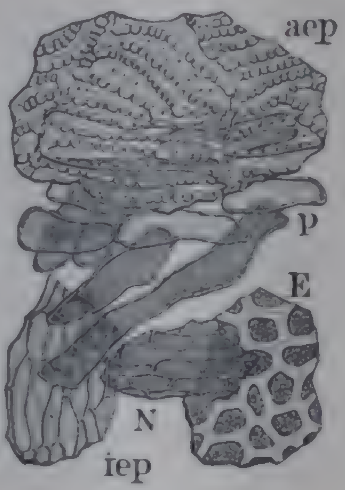

Fig. 159.

Fig. 158.—Date. Elements of pericarp in surface view. *epi* epicarp with *sto* stoma; *hy* hypoderm; *st* stone cells; *tan* tannin cell; *sp* spiral and *r* reticulated vessels; *mes*² spongy inner mesocarp; *end* endocarp. × 160. (K.B.W.)

Fig. 159.—Date. Elements of seed in surface view. Spermoderm: *aep* outer epiderm, *p* parenchyma, *iep* inner epiderm. *N* perisperm. *E* endosperm. ×160. (K.B.W.)

The *fibro-vascular bundles,* according to Hanausek, are accompanied by cells containing rounded, siliceous bodies like those occurring in the stegmata of the cocoanut (which see) and in the epiderms of the bract and perianth of the pineapple (which see).

Spermoderm (Fig. 157, *S*; Fig. 159).—Three layers are present: (1) *outer epiderm* (*aep*) of elongated cells, with thickened porous walls, transversely or irregularly arranged; (2) *parenchyma* (*p*), of transversely or diagonally elongated cells, some with brown contents, in loose contact like the tube cells of cereals; and (3) *inner epiderm* (*iep*) of longitudinally elongated cells with inner cuticle.

Perisperm (Figs. 157 and Fig. 159, *N*).—Somewhat transversely elongated cells about two thick form an indistinct layer.

Endosperm (Figs. 157 and 159, *E*).—This tissue is a striking example of reserve material in the thickened cell walls. Cross sections show that the outer cells have a cuticle and are radially elongated with few pores, while those farther inward are isodiametric and strongly porous. Oil is conspicuous in the cells; starch is absent.

CHIEF STRUCTURAL CHARACTERS.—Fruit an elongated, smooth, red or yellow, one-seeded berry. Seed hard, elongated, with groove on ventral side and spot marking position of minute embryo on dorsal side. Spermoderm thin; perisperm still thinner; endosperm bulky.

Pericarp with stone cell zone and tannin cell zone; fibro-vascular bundles accompanied by cells containing siliceous bodies; endocarp of elongated, often somewhat thickened cells. Spermoderm with outer epiderm of porous cells and middle layer of tube cells often with dark contents; endosperm with reserve material in thickened walls.

CHEMICAL COMPOSITION.—Atwater and Bryant[1] report 2 analyses of the edible part of cured dates constituting 90 per cent of the whole product.

COMPOSITION OF DATES (ATWATER AND BRYANT)

	Water	Protein	Fat	N-f. ext.*	Ash
	%	%	%	%	%
Min........	9.9	2.1	0.6	70.4	1.1
Max.......	20.8	2.2	5.1	86.3	1.5
Aver.......	**15.4**	**2.1**	**2.8**	**78.4**	**1.3**

* Includes fiber.

Date Stones.—Analyses by Storer[2] of date stones and by Winton[3] of ground roasted date stones used as a substitute for coffee given below

COMPOSITION OF DATE STONES

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Stones from light dates..	7.71	5.16	8.95	53.06	24.07	1.05
Stones from dark dates..	10.83	5.75	8.05	52.29	22.06	1.02
Date-stone coffee........	5.52	6.69	11.20	59.00	15.84	1.75

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

[2] Bussey Inst. Bul. 1874/6, 1, 375.

[3] Connecticut Agr. Exp. Sta. Rep. 1897, p. 16.

show over twice as much nitrogen-free extract as fiber, a considerable portion of which probably represents cell-wall substance hydrolyzable by acid. The cell contents consist chiefly of protein and fat.

Carbohydrates.—Results by Fattah and Cruess [1] indicate that dates grown in Mesopotamia are higher in solids and total sugars than those grown in California. The variety deglet noor was always high in sucrose, even when ripe; other varieties contained considerable sucrose when green but this largely disappeared on ripening. Tannin also decreased during ripening.

Sievers and Barger [2] state that sucrose is the principal sugar of deglet noor dates but that inversion, beginning before picking, causes the formation of as much as 20 to 25 per cent of invert sugar. Overinversion makes the fruit too sticky, and moisture over 25 per cent or heating above 100° C. causes souring or other spoilage.

Sorbitol.—Reif [3] found sorbitol, an alcohol derived from dextrose.

Minor Mineral Constituents. *Iron.*—Dried dates 18 mg. per kilo, as sold (Bunge).[4] Dried dates 50.7 mg. per kilo, as sold (Peterson and Elvehjem).[5]

Copper.—Dried dates 2.4 mg. per kilo, as sold, 3.0 mg. per kilo dry basis (Guérithault).[6] Dried dates 3.8 mg. per kilo, as sold (Lindow, Elvehjem, and Peterson).[7]

Zinc.—Dried stoned dates 3.4 mg. per kilo, as sold (Bertrand and Benzon).[8]

Arsenic.—Dried dates 0.12 mg. per kilo, as sold (Jadin and Astruc).[9]

[1] Plant Physiol. 1927, **2**, 349.

[2] U. S. Dept. Agr. 1930, Tech. Bul. **193**.

[3] Z. Unters. Lebensm. 1934, **68**, 179.

[4] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] Compt. rend. 1920, **171**, 196.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

[9] Compt. rend. 1912, **155**, 291.

FRUITS OF THE PINEAPPLE FAMILY

(*Bromeliaceæ*)

Of the members of this family only the pineapple, yielding an acid, saccharine fruit, is of importance as a food.

PINEAPPLE

Ananas sativus Schult. f. = *Ananassa sativa* Lind. = *Bromelia Ananas* L.

Fr. Ananas. Sp. Anana. It. Ananasso. Ger. Ananas.

As regards habit of growth and morphology of the fruit, the pineapple stands in a class by itself. The plant, a native of the Western Hemisphere, is herbaceous and the fruit is not only multiple and fleshy but bears a bunch of leaves at its extremity. In Florida the pineapple thrives on calcareous soil with only a thin layer of humus. It is produced in Hawaii in enormous quantities for local consumption and especially for canning.

The cultivated varieties do not usually produce seeds but are perpetuated by planting the crowns, the slips that form just below the fruit, the suckers that form near the bottom, or the root buds (rattoons).

Hume and Miller[1] divide the varieties cultivated in the United States into three groups: (1) Queen group, of which Golden is the type, fruit deep yellow, flesh yellow, eyes sloping upward from sides; (2) Cayenne group, of which Smooth Cayenne is the type, flesh light yellow, eyes broad and flat, not elongated at nipple; and (3) Spanish group, flesh white, eyes flat but elevated at corners of bracts. In most varieties the fruit is more or less ovoid, in the Abachi, however, it is narrow, long, and tapering, and in the Porto Rico broad and tapering.

In addition to cored slices, the grated pulp from the trimmings is canned and the juice is sterilized in bottles. Glacé pineapple is also prepared. Further details of the industry are given by Bailey and Bailey.[2]

MACROSCOPIC STRUCTURE.—The *flowers* are in a dense upright spike. Each flower has an inferior, three-celled, many-ovuled ovary on which are borne the perianth tube with its six lobes, the six stamens, and in the center the single style surmounted by three stigmas. Subtending each flower is a pointed bract. After flowering, the base of the bract, the perianth tube, the sides of the pericarp, and the rachis develop greatly in thickness forming a juicy consolidated tissue.

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[1] Florida Agr. Exp. Sta. 1904, Bul. 70.

[2] Food Products from Afar, New York, 1922, p. 182.

The *fruit* is accordingly multiple and a syncarp, crowned with a bunch of stiff, toothed leaves. On the surface, each component fruit (" berry ") is characterized by its more or less hexagonal outline, the harsh perianth lobes closing over a chamber in which are the remains of the stamens, style, and stigmas, and the equally harsh upwardly directed bract with its toothed edges and tapering point. On mellowing, the green color changes usually to yellow, red, and brown, in various proportions. Each individual fruit may be torn away from its neighbor, although not through any well-defined separating tissues, as is often done in serving. Tangential sections show the locules of the fruits, each usually with minute undeveloped ovules.

Hume and Miller describe the wild Honduras variety, of worthless quality, in which about three slightly rough, brown *seeds*, 5 mm. long, are developed to each eye. A few such seeds, enclosed in a thin aril, occur in canned pineapple from China, the pared fruit of which, being small (about 10 cm. long), is either packed whole, except for the core, or in large pieces (not slices) cut spirally to the locules, apparently to remove the seeds. The fruit of the Chinese variety, unlike the wild Honduras, is of delicious quality.

MICROSCOPIC STRUCTURE.—Winton describes the pineapple tissues in the second edition of Moeller's Mikroskopie der Nahrungs- und Genussmittel (1905) and the two editions of Microscopy of Vegetable Foods (1905, 1916) with a single cut showing the raphides.

Rachis.—The fleshy core or rachis differs in structure from the fruit flesh, made up of bract, perianth, and pericarp, chiefly in the greater number of fibro-vascular bundles and the greater number of bast fibers in each.

Bract (Fig. 160).—Five layers are present in the free end, except at the very tip and edges where there are fewer: (1) *outer epiderm* (*aep*^{1}) of wavy-walled, more or less quadrilateral stegmata containing siliceous bodies, in irregular longitudinal rows, also curious scale-like hairs (*t*) and, toward the tip, stomata; (2) *hypoderm* of longitudinally elongated cells with porous walls, several thick; (3) *mesophyl* of parenchyma, in the lower part like that described below under fruit flesh; (4) *elongated cells* with porous, sclerenchymatized walls as in the hypoderm; and (5) *inner epiderm* (*iep*^{1}) of stegmata similar to those of the outer epiderm but often transversely elongated and with larger siliceous bodies which occur most frequently at the tip and are absent at the base.

Perianth (Figs. 160 and 161).—The portion free from the consolidated fruit flesh has the same general structure as that of the bract. In cross section of the fruit the *stegmata* (*ste*), in addition to the primary walls, are seen to have secondary thickenings of the inner and radial walls which extend about the siliceous contents, reducing the lumen to a mere line beneath the outer wall. The siliceous body is rounded with numerous minute warts. Similar stegmata occur on the fibers of the cocoanut. Cross sections also show the depressions in which occur the stomata (*sto*). The walls of the *inner epiderm* (*iep*^{2}) are usually strongly zigzag and more striking than the merely wavy walls of the corresponding cells of the bract. Some of the cells at the tip contain siliceous bodies.

Pericarp (Fig. 160).—Beginning with the free tip of the pericarp within the chamber formed by the overarching perianth and extending inward, the layers number the same as, and are analogous to, those of the bract and perianth but the details of structure are different. The tissues are (1) *epicarp* (*epi*) of wavy-walled, more or less quadrilateral cells, often in irregular longitudinal rows, but not containing siliceous bodies and not accompanied by stomata or hairs; (2) *hypoderm* (*hy*^{2}), of isodiametric or transversely (not longitudinally) elongated cells, with walls more strongly thickened and porous than in the bract or perianth; (3) *mesocarp* (*mes*) of rounded parenchyma cells, some of the larger containing raphides (*r*), and fibro-vascular bundles; (4) elongated *sclerenchyma cells* (*scl*) with thin but porous walls; and (5) *endocarp* (*end*), also of elongated cells, often crossing those of the adjoining layer, but with thin, non-porous walls.

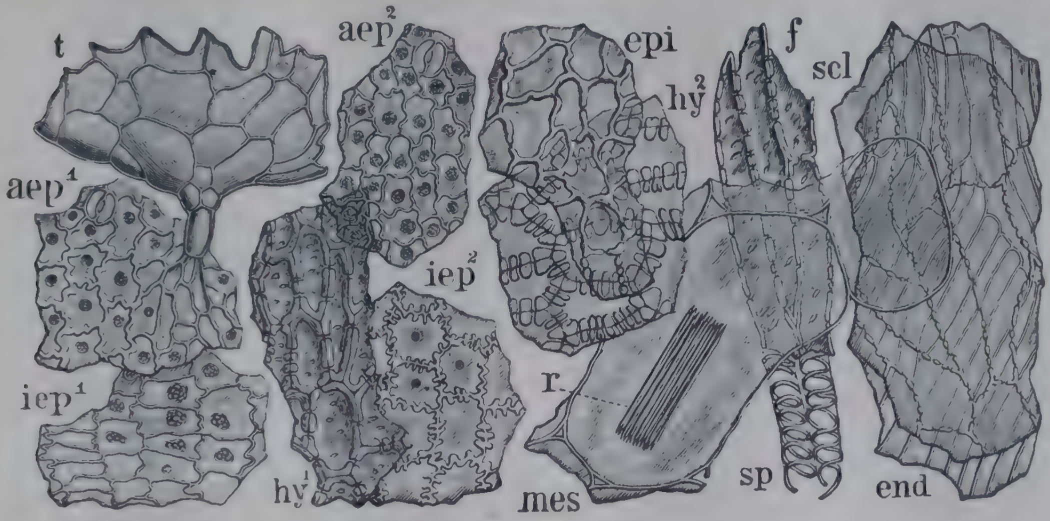

Fig. 160.—Pineapple. Elements of fruit in surface view. Bract: *aep*^{1} outer epiderm with stoma and *t* scale-like hair, *iep*^{1} inner epiderm. Perianth tube: *aep*^{2} outer epiderm with stoma and hair scar, *hy*^{1} hypoderm, *iep*^{2} inner epiderm. Pericarp: *epi* epicarp, *hy*^{2} hypoderm, *mes* mesocarp with *r* raphides, *f* bast fibers, *sp* spiral vessels, *scl* sclerenchyma layer, *end* endocarp. × 160. (K.B.W.)

As here used, the mesocarp includes the edible fruit flesh belonging not only to the pericarp but also to the bases of the bract and perianth but not to the fleshy rachis. Because of the raphides, the eating of raw pineapples often makes the mouth sore. Of the bundle elements, the *bast fibers* (*f*) are the most abundant, enclosing the relatively few vascular elements. The *spiral vessels* reach 25 μ and often have two spirals. It is the bast fibers that lodge between the teeth in eating pineapples.

Seeds found in Chinese canned pineapples have the following structure:

Aril (Fig. 162, *A*).—A thin, transparent colorless skin, two to four cells thick, forms the aril. Papillæ with somewhat thickened yellow outer walls arise from the *outer epiderm* and pores occur in some of the cells. The cells of the *inner epiderm* are transversely elongated.

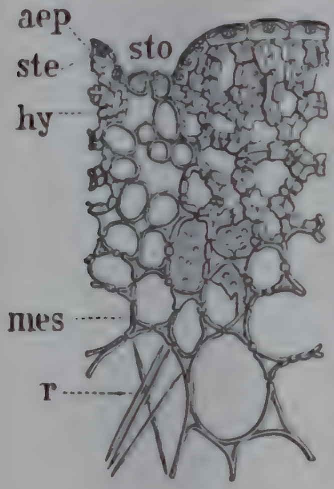

FIG. 161.

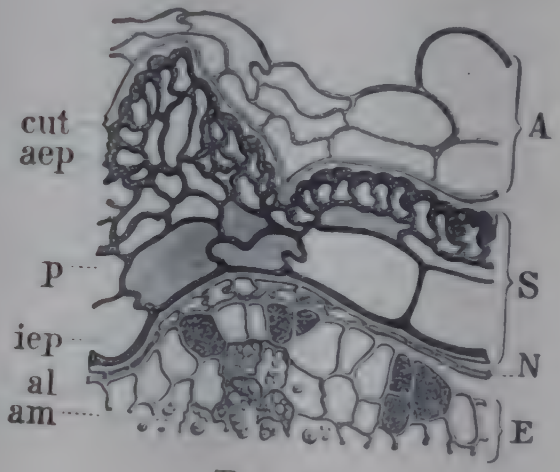

FIG. 162.

FIG. 161.—Pineapple. Outer perianth in cross section of the fruit. *aep* outer epiderm with *sto* stoma and *ste* stegmata; *hy* hypoderm; *mes* mesophyl with *r* raphides. × 160. (K.B.W.)

FIG. 162.—Pineapple. Seed in cross section. *A* aril. *S* spermoderm: *aep* outer epiderm with *cut* cuticle, *p* brown parenchyma, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *am* starch cells. × 160. (K.B.W.)

Spermoderm (Fig. 162, *S*).—The three layers, which vary somewhat beneath the wrinkles, are: (1) *outer epiderm* (*aep*) of narrow, longitudinally elongated, brown cells with thick white cuticle (*cut*) and thick walls; (2) *middle layer* (*p*) of transversely elongated cells, one or more thick, with brown walls; and (3) *inner epiderm* (*iep*) of deep brown, transversely elongated cells with a cuticle.

Perisperm (Fig. 162, *N*).—This forms an exceedingly thin layer of collapsed cells, separated readily as a skin and evident in cross section on treatment with Javelle water.

Endosperm (Fig. 162, *E*).—Typical *aleurone cells* (*al*) form an outer layer, one cell, occasionally two cells, thick. The remainder of the endosperm consists of *starch cells* (*am*) with thin, often wavy walls. The starch grains occur singly or in small aggregates. They are rounded or truncated, up to 10 μ in diameter, with central hilum.

Embryo.—Minute.

CHIEF STRUCTURAL CHARACTERS.—Fruit multiple (syncarp); rachis fleshy; each component fruit (berry) subtended by a pointed bract and covered by perianth lobes; fruit flesh a consolidation of pericarp with lower part of both bract and perianth; pericarp three-celled. Seeds abortive in common American varieties, well developed in certain wild and Chinese varieties.

Rachis and fruit flesh of characterless parenchyma, occasional raphides cells, and fibro-vascular bundles consisting largely of bast fibers; bundles most numerous in rachis. Bracts and perianth with epidermal stegmata, each with siliceous body, and scale-like hairs. Endosperm with rounded or truncated starch grains up to 10 μ.

CHEMICAL COMPOSITION.—Preliminary to the study of canned pineapple, Chace, Tolman, and Munson [1] analyzed 38 specimens of the fresh fruit from Florida, Cuba, Bahama, Puerto Rico, and Jamaica. During the same year Hume and Miller [2] carried out a similar investigation on 12 samples of Florida pineapples, ranging from 0.7 to 4.1 kilos in weight and with edible portion ranging from 50 to 67 per cent, representing the three types Queen, Cayenne, and Spanish. Kelley [3] reports on the composition of 21 samples of ripe Hawaiian pineapples and samples collected at different stages of maturity. An analysis by Flack [4] of South African fruit and one by Pratt and Del Rosario [5] of Philippine fruit are here tabulated with the foregoing, the samples in all cases representing the peeled and cored fruit. See page 492.

Blair and Wilson [6] report the following averages: weight of one fruit without crown, 65 determinations, 966 grams; edible portion, 33 determinations, 61 per cent of fruit; available juice, 85 determinations, 92.8 per cent of edible portion; total solids in whole fruit, 66 determinations, 15.18 per cent; and protein, 63 determinations, 0.40 per cent of edible portion. Their figures on the composition of the juice are given below in the table.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Florida Agr. Exp. Sta. 1904, Bul. **70**, 36

[3] J. Ind. Eng. Chem. 1911, **3**, 403.

[4] Chem. News. 1912, **105**, 99.

[5] Philippine J. Sci. 1913, **8**, 59.

[6] Florida Agr. Exp. Sta. 1910, Bul. **101**.

COMPOSITION OF PEELED AND CORED PINEAPPLES

	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, total	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%
C. T. and M.:										
Min.	10.78	1.02	0.21	0.43	8.20	1.76	2.98	....	0.27	32
Max.	18.86	1.83	0.57	1.21	15.28	9.75	10.48	....	0.55	85
Aver.	**14.17**	**1.52**	**0.42**	**0.86**	**11.90**	**3.91**	**7.59**	....	**0.40**	**53**
H. and M.:										
Min.	9.90	0.58	0.32	0.84†	4.28†	....	.....	....	0.41	..
Max.	14.40	3.74	1.19	3.02†	13.37†	....	.....	....	0.75	..
Aver.	**12.48**	**1.57**	**0.49**	**1.59†**	**9.92†**	....	.....	....	**0.51**	..
Kelley:										
Ripe										
Min.	.....	....	0.37	0.31	9.15	2.78	3.63	....	....	..
Max.	.....	....	0.56	1.66	15.23	6.20	10.12	....	....	..
Aver.	.....	....	**0.50**	**1.06**	**12.11**	**4.23**	**7.88**	....	....	..
Green, Aver.	**6.89†**	....	....	**0.56**	**5.01**	**3.29**	**1.72**	**0.17**	....	..
Green, ripened Aver.	**5.79†**	....	....	**0.73**	**4.12**	**1.26**	**2.40**	**0.22**	....	..
¼ ripe Aver.	**8.68†**	....	....	**0.93**	**7.16**	**2.74**	**4.42**	....	....	..
½ ripe Aver.	.....	....	....	**0.93**	**9.71**	**2.97**	**6.74**	....	....	..
Flack	16.14‡	....	0.49	....	.....	....	.....	0.33	0.70	..
P. and Del. R.	13.80	2.10	0.44	0.79	9.41	3.36	5.74	....	0.36	46

* Cc. *N*/10 acid per 100 grams fruit. † In juice. ‡ Fat 1.11, N-f. ext. 13.51%.

Composition of Pineapple Juice.—Kayser,[1] in 2 samples of freshly pressed and filtered juice, secured the following results in grams per 100 cc.: solids 16.72 and 16.14, citric acid 0.63 and 0.60, acids calculated as citric acid 0.58 and 0.58, invert sugar 4.0 and 3.2, and sucrose 8.64 and 9.10 per cent. The average of 100 determinations each on the juice of Florida pineapples, made by Blair and Wilson,[2] gave: acids as citric 0.98, total sugars 12.07, reducing sugars 2.60, and sucrose 9.47 per cent.

Relation of Size to Composition.—Blair and Wilson[3] showed that large pineapples contain more sugar but less acid than small and have a greater ratio of reducing sugars to sucrose.

Influence of Fertilizers on Composition.—The last-named authors were unable to show any appreciable influence of fertilizers on the sugar- and acid-content but suggested the possible correlation between the nature of the plant food and the shipping qualities.

Respiration.—Gore,[4] working with 2 varieties of pineapples, noted a maximum of 104 mg. of carbon dioxide per kilo per hour at 31.2° C. and a minimum of 5 mg. at 2.5° C.

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[1] Z. öffentl. Chem. 1909, **15**, 187.

[2] Loc. cit.

[3] Loc. cit.

[4] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

Acids.—Results by Kayser[1] indicate that *citric* is the only free acid in the pineapple and that little if any of that acid is in combination. Determinations of citric acid and acidity calculated as that acid gave practically identical results. Nelson,[2] by the ester distillation method, obtained *citric acid* about 87 per cent and *l-malic acid* about 13 per cent of the total acids.

Colors.—Determinations by Magistad[3] gave 1.0 to 2.5 mg. per kilo of *carotene* in pineapple flesh and smaller amounts of *xanthophyl.*

Mineral Constituents.—Chace[4] analyzed the ash of 2 samples but failed to give the percentage of ash. Following are the percentages in the fresh edible portion calculated from his analysis, assuming 0.40 per cent of crude ash in each:

	K_2O	CaO	MgO	P_2O_5	SO_3	Cl
	%	%	%	%	%	%
I	0.24	0.04	0.02	0.03	0.002	0.01
II	0.23	0.02	0.01	0.02	0.015	0.02

Minor Mineral Constituents. *Iron.*—Edible portion 3.2 mg. per kilo, fresh basis (Peterson and Elvehjem).[5] Edible portion, 2 samples, 2.5, 3.6 mg. per kilo, fresh basis (Toscani and Reznikoff).[6]

Copper.—Edible portion 0.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

Zinc.—Edible portion 2.6 mg. per kilo, fresh basis (Bertrand and Benzon).[8]

Arsenic.—Edible portion 0.08 mg. per kilo, fresh basis (Jadin and Astruc.).[9]

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[1] Loc. cit.

[2] J. Am. Chem. Soc. 1925, **47**, 1177.

[3] Plant physiol. 1935, **10**, 187.

[4] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] J. Nutrition 1934, **7**, 79.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

[9] Compt. rend. 1912, **155**, 291.

FRUITS OF THE BANANA FAMILY

(*Musaceæ*)

THE family is named for its most important genus, *Musa*, to which belong the several species yielding fruits, known collectively as bananas.

The bananas when green are starchy, when fully ripe saccharine. Only a small amount of acid is present. Amyl acetate is the chief odorous constituent. The presence of tannin modifies the flavor.

BANANA

Musa sapientum L.

Fr. Banane. Sp. Plátano. It. Banano. Ger. Banane.

In tropical regions the banana in its broad sense, including the plantain or plantain banana (*M. paradisiaca* L.) which is now classed by some as a variety and by others as a sub-species, furnishes millions with their chief source of nutrition. It is there more commonly eaten cooked, while still hard, as a vegetable, than uncooked out of hand.

The plantain (known in Mexico as *plátano macho*) has a larger but coarser fruit than the true banana (*plátano dulce*) and is suited only for cooking. A dwarf and small-fruited banana (*M. Cavendishii* Lamb. = *M. chinensis* Sweet) yields excellent fruit while another species (*M. troglodytarum* L.), classed by Baker as a subspecies under *M. paradisiaca*, yields fruit fed to elephants in India. Of special scientific interest, because it produces mature seeds, is the inedible wild banana of the Orient (*M. seminifera* Lour. = *M. paradisiaca seminifera* Baker).

In the United States the banana is the poor man's fruit. It bears well transportation while still hard and green, mellowing, with the accompanying change of starch to sugar, being brought about by holding in special storage houses where free circulation of air and proper temperature are carefully regulated. Wolfe[1] states that ethylene hastens the ripening.

Red bananas (var. *rubra* Baker) have been largely displaced in commerce by the yellow type.

Banana meal is made from the green fruit while still starchy. Tibbles[2] gives as a common ration for natives on estates two pounds of banana meal and one-quarter pound of salt pork. Dreher [1] states that processes have been perfected in Jamaica for preparing, from small unmarketable bunches, dried fully ripe bananas ("banana figs"), a breakfast food ("banana chips"), and banana meal. Banana starch is described in Volume I.

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[1] Bot. Gaz. 1931, **92**, 337.

[2] Foods, etc., London, 1912, p. 628.

MACROSCOPIC STRUCTURE.—Although herbaceous the banana *plant* is so large as to be popularly considered a tree. It grows to the height of 10 meters, has leaves up to 2.5 meters long on petioles about 0.5 meter long at the top of a trunk-like stalk (consisting of leaf sheaths), and bears fruit when only one to two years old, after which new shoots from the roots take its place.

The spike that grows out from among the bases of the petioles bears *flowers* in transverse rows, half encircling the rachis or flower stalk. The flowers are hermaphrodite, but those in the basal part of the spike have abortive male organs while those in the tip have abortive female organs. Those in the same row, forming in the fruit a hand, are subtended by a large and showy purple bract. The three-toothed calyx is at first tubular but later splits on one side; opposite this is a single entire or three-toothed petal. Of the six stamens one is abortive. The inferior ovary is three-celled with numerous ovules borne on axial placentæ.

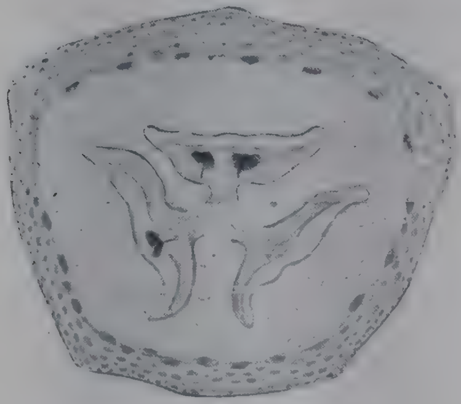

FIG. 163.

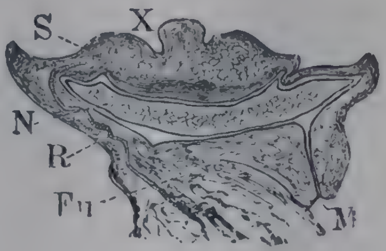

FIG. 164.

FIG. 163.—Banana. Fruit in cross section showing bundles and locules with seeds. × 1. (K. B. W.

FIG. 164.—Banana. Abortive seed in longitudinal section, showing attachment. *Fu* funiculus; *R* raphe; *X* chalaza; *S* spermoderm; *N* perisperm; *M* micropyle. × 25. (K.B.W.)

On ripening, the *fruit* becomes elongated, angular, and red or yellow in color, with the scar of the deciduous perianth at the apex. Viewed in cross section (Fig. 163) the rind (1 to 4 or 5 mm.) is deep yellow and glossy, consisting of bundle groups almost in contact, decreasing in number but increasing in size inward. On stripping off the rind, longitudinal stripes, corresponding to the inner large spots of the cross section, are clearly visible and show their obvious bundle character. Numerous transverse-tangential branches of the main (longitudinal) bundles form transverse stripes visible on the surface after stripping and as minute spots in radial section.

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[1] U. S. Consular & Trade Rep. 1911, pp. 171 and 503.

At the center of the flesh (edible portion) the three narrow, slit-like locules are seen in cross section to form irregular, inwardly bowed curves arranged in a triangle. These contain black or dark abortive *seeds* borne on axial placentæ. Fig. 164 is of an abortive seed in longitudinal section, magnified 25 diameters, showing the broad funiculus (*Fu*) from which the raphe bundle (*R*) proceeds, the spermoderm (*S*) with chalaza (*X*), the nucellar tissue or perisperm (*N*), and the micropyle (*M*). An embryo is entirely lacking.

The axis of the fruit and the three partitions extending from it to the main fruit flesh are broad and succulent.

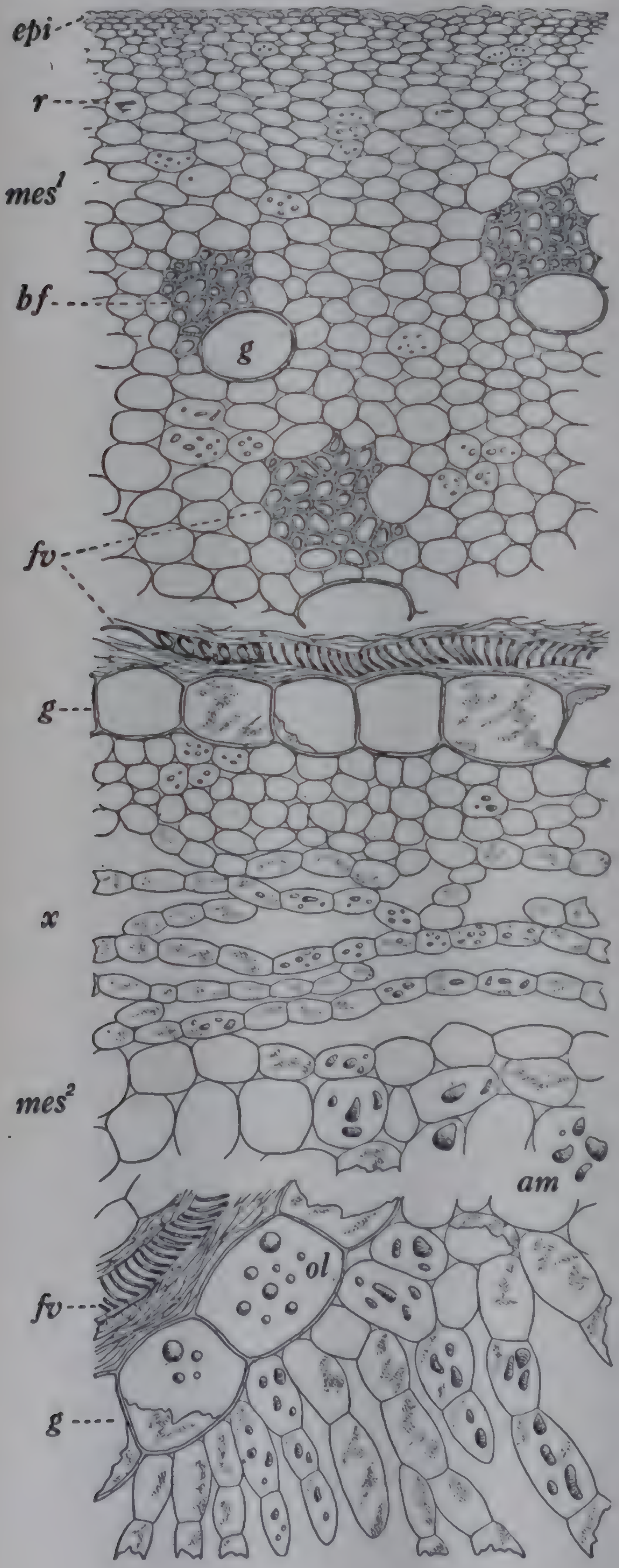

FIG. 165.—Banana. Fruit in cross section. *epi* epicarp; *mes*¹ outer mesocarp with starch grains and *r* raphides; *mes*² middle mesocarp showing *x* transverse chains of starch cells through which the rind separates; below, inner mesocarp with radial chains of starch cells. *bf* bast fiber bundles; *fv* fibrovascular bundles; *g* tannin cells with *ol* oleoresin drops; *am* starch grains. × 55. (K.B.W.)

Separation through the partitions may often be readily effected by gently pulling apart the tissues. Longitudinal bundles run through the placental tissues with lateral branches to the seeds.

MICROSCOPIC STRUCTURE.—Winton[1] describes the histology of the pericarp. Hanausek[2] writes on the microscopic detection of banana meal. Earlier authors describe banana starch. The following description applies to the common yellow banana and the red banana sold in northern markets.

Pericarp (Figs. 165 and 166).—The tissues may be divided, somewhat arbitrarily, into six layers: (1) *epicarp* (*epi*) of isodiametric or somewhat tangentially elongated cells with thick outer walls and striated cuticle, also especially near the ends of the fruit, stomata; (2) *hypoderm* (*hy*) of porous-walled cells, increasing in size inward, some containing raphides (*r*); (3) *outer mesocarp* (mes^1) of rounded moderate-sized starch cells among which run in the outer part fiber bundles (*bf*) and, further inward, fibro-vascular bundles (*fv*), in both cases accompanied by oleoresin cells (g, g^1, g^2); (4) *middle mesocrap* (mes^2, *mes*), forming the bulk of the fruit, of large rounded starch cells, fibro-vascular bundles, and oleoresin cells; (5) *inner mesocarp* of radially arranged chains of starch cells in loose contact, also fibrovascular bundles (*fv*) and oleoresin

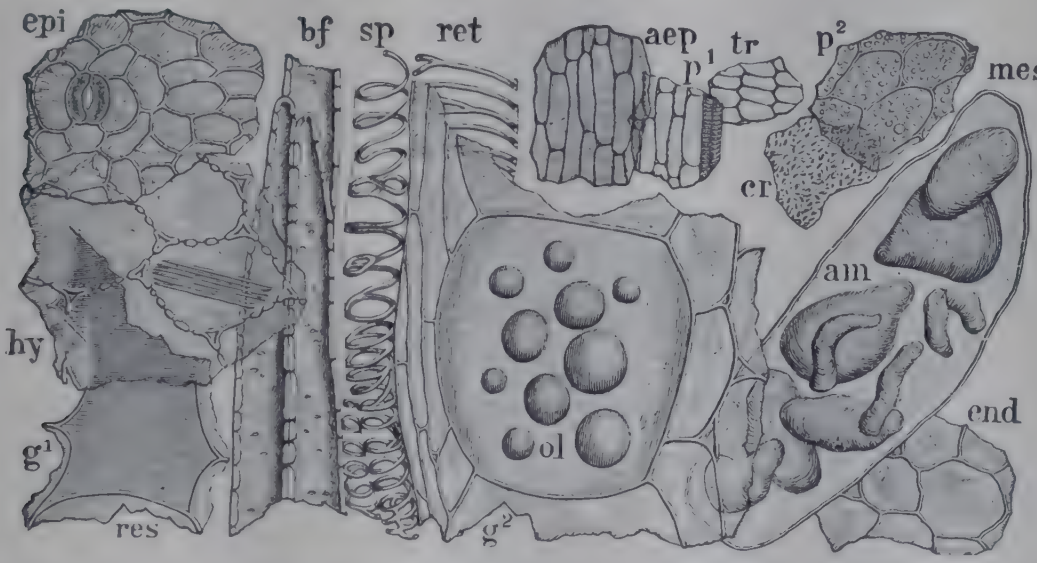

FIG. 166.—Banana. Elements in surface view. Pericarp: *epi* epicarp with stoma, *hy* hypoderm with raphides, *res* hardened secretion in g^1 oleoresin cell, *bf* bast fibers, *sp* spiral and *ret* reticulated vessels, *ol* drops of secretion in g^2 oleoresin cell, *mes* middle mesocarp cell with *am* starch grains, *end* endocarp. Spermoderm: *aep* outer epiderm, p^1 parenchyma with two raphe vessels, *tr* cross cells. Perisperm: *cr* crystal cells, p^2 parenchyma. × 160. (K.B.W.)

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[1] Moeller: Mikros. Nahr.-Genussm., Berlin, 2. Aufl. 1905, p. 461; Winton: Micros. Veg. Foods, New York, 1st Ed. 1905, p. 393.

[2] Z. Unters. Nahr.-Genussm. 1910, **20**, 215.

cells (*g*); and (6) *endocarp* (*end*) of radially much elongated, thin-walled cells, polygonal in surface view.

Between the medium-sized cells of the outer mesocarp and the large cells of the middle mesocarp forming the bulk of the tissues are several rows of small cells arranged in transverse chains in loose contact (Fig. 165, *x*), through which separation of the rind takes place. The yellowish gelatinous tissues of the hypoderm and about the main fiber and fibro-vascular bundles of the outer mesocarp are starch-free. Their appearance is due to turgescence.

The *starch grains* (Fig. 166, *am*) are smallest in the outer mesocarp and increase in size inward until the maximum is soon reached. Among the forms of the large grains are sac-, sausage-, flask-, and sickle-shaped, also irregular forms with protuberances. They vary in length up to 85 μ and down to 2 or 3 μ and have distinct rings about the excentric hilum. The excentricity varies from 1:6 to 1:10. Clefts through the hilum occasionally occur. During the ripening the starch is converted into sugars, the gradual disintegration and solution being evident under the microscope.

Fig. 165 shows the course of the *fibro-vascular bundles* and Fig. 166 the characters of the bundle elements. The bast fibers (Fig. 166, *bf*) are broad but with relatively thin walls. Characteristic of the spiral (*sp*) and spirally reticulated (*ret*) vessels are their great width (up to 100 μ), the loosely wound thickenings, and the curious loops.

The remarkable *oleoresin cells* (Figs. 165 and 166, *g*, g^1, g^2) are characterized by (1) their proximity to the bundles, often touching them, (2) their large size, (3) their arrangement in chains like the vittæ of umbelliferous fruits, and (4) their contents which in the immature stage are in drops but on ripening become solid. This solid form (*res*) appears first in the cells of the rind, solid and liquid contents often being evident in the same specimen. Ferric chloride, or even the knife used in cutting the section, stains the contents a deep blue (not violet) color, showing the presence of tannin substances. The chief constituents, however, are water-insoluble substances including possibly the ethers, to which the banana owes its flavor, associated with essential oil and fatty oils. The hardening of the contents suggests resins. In the absence of more definite knowledge of the contents, the term " oleoresin cells " is used to show the relationship to the cells of other fruits that contain volatile oils and resins.

Spermoderm (Fig. 166).—Three tissues of the abortive seed belong to the spermoderm: (1) *outer epiderm* (*aep*) of thin-walled, longitudinally elongated cells; (2) *parenchyma* (p^1), also of elongated cells, with spiral vessels of the raphe; and (3) *cross cells* (*tr*), side by side in rows, which may form the inner epiderm.

Perisperm (Fig. 166).—This is represented by a tissue showing no cell structure but containing minute crystals (*cr*), also a distinctly cellular tissue (p^2) containing granular contents and here and there rounded bodies.

Endosperm.—No endosperm tissues were found in the immature seeds but Keenan and Wildman,[1] who studied the seeds of several varieties of bananas obtained from the United Fruit Company, noted octohedral crystals embedded in masses of very small starch grains in the endosperm, which were identical optically and microchemically with the crystalline globulin obtained by Jones and Gersdorff [2] from squash and cantaloupe seeds.

Chief Structural Characters.—Fruit elongated, yellow or red, angled with scar of perianth at end; rind in cross section showing numerous yellow spots, each with bundle; edible flesh cream-colored, bundles evident under a lens; locules three, slit-like containing black or brown abortive seeds.

Hypoderm containing raphides; outer mesocarp of starch parenchyma with fiber bundles in outer part and fibro-vascular bundles in inner part; rind separating through transverse chains of starch cells between outer and middle mesocarp; middle mesocarp with large round starch cells; inner mesocarp with radial chains of starch cells; oleoresin cells accompanying bundles; vessels broad with thickenings often far apart; starch grains, up to 85μ, of various elongated forms with excentric hilum and distinct rings.

MICROSCOPY OF BANANA PRODUCTS.—**Banana Figs** and **Banana Meal** contain all the elements inside of the outer mesocarp: starch, vessels, oleoresin cells, and seeds.

Banana Starch.—See Commercial Starches, Volume I.

CHEMICAL COMPOSITION.—Chace, Tolman, and Munson [3] report analyses of the flesh (edible portion) of 15 samples of bananas grown, with three exceptions, in Cuba, weighing 31 to 130 grams and containing 62 to 84 per cent of flesh. Reich,[4] in a study of ripe and unripe bananas as well as their dried and milled products, analyzed the flesh of 7 samples of fresh bananas from Surinam. Thompson,[5] following the same methods as Chace, Tolman, and Munson, carried out analyses of the flesh of 5 samples of Hawaiian bananas containing 64 to 76 per cent of pulp.

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[1] J. Biol. Chem. 1930, **88**, 425.

[2] Ibid. 1923, **56**, 79; 1927, **75**, 213.

[3] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[4] Z. Unters. Nahr.-Genussm. 1911, **22**, 208.

[5] Hawaii Agr., Exp. Sta. Rep. 1914, p. 62.

COMPOSITION OF BANANA FLESH

	Solids, total	Solids, insol.	Protein	Fat	Acids as malic	Sugars, total	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
C. T. and M.:											
Min.*.....	21.60	2.23	0.84	....	0.23	15.36	3.16	0.30	....	....	0.70†
Max.*.....	34.55	4.52	1.36	....	0.59	25.66	21.43	17.59	....	....	1.10†
Aver.*....	**27.54**	**3.40**	**1.16**	....	**0.41**	**20.20**	**11.69**	**10.37**	....	....	**0.86†**
Reich:											
Min.......	20.84	2.29	0.91‡	....	0.31§	15.56	6.72	0.95	0.57	0.56§	0.84
Max......	28.37	6.42	2.41‡	....	0.40§	21.86	19.73	14.63	4.20	0.66§	1.12
Aver......	**25.13**	**3.15**	**1.72‡**	....	**0.36§**	**19.39**	**11.12**	**8.27**	**1.30**	**0.62§**	**0.95**
Thompson:											
Min.......	21.28	2.45‡	1.07	0.05	0.32	14.49	8.18	0.00	....	0.25	0.75‡
Max.......	32.22	10.30‡	1.79	0.52	0.57	26.20	21.16	9.59	....	0.59	0.96‡
Aver......	**28.13**	**5.09‡**	**1.44**	**0.23**	**0.46**	**20.24**	**15.12**	**5.11**	....	**0.37**	**0.72‡**

* Results on solids and ash represent 15 samples, the others only 8 to 13 samples. † Alkalinity 65 to 110, aver. **91**, cc. $N/10$ acid per 100 grams of fruit. ‡ 4 samples. § 3 samples.

No comprehensive analyses of the bananas produced in enormous quantities in Central America, Colombia, and various parts of the West Indies and shipped to the United States are available.

Since the starch, which constitutes the great bulk of the carbohydrates at the time the fruit reaches its full size, is rapidly converted into sugars during ripening, definite data on the stage of maturation and ripeness are important in interpreting an analysis.

Dacanay[1] and Salvador[2] analyzed the flesh of 19 samples of fruit of various species and varieties of the genus *Musa* varying in weight from 35 to 261 grams. The flesh ranged from 54.70 to 84.0 per cent and its composition as follows: water 65.29 to 83.08, protein 0.69 to 1.84, fat 0.28 to 0.80, reducing sugars 4.09 to 25.00, sucrose 0.15 to 17.73, other carbohydrates (nitrogen-free extract less sugars) 0.72 to 6.73, fiber 0.28 to 2.12, and total ash 0.77 to 1.16 per cent.

Valenzuela and Wester[3] analyzed the flesh (47.6 to 83.4 per cent) of 7 varieties, including a pink variety from Guam, with the following results: water 63.66 to 73.80, aver. **67.78**, protein 0.93 to 1.78, aver. **1.42**, fat 0.14 to 2.31, aver. **0.88**, sucrose 3.45 to 10.4, aver. **6.80**, reducing sugars 13.78 to 31.25, aver. **18.88**, fiber 0.48 to 0.52, aver. **0.50**, and ash 0.52 to 1.05, aver. **0.81** per cent.

[1] Philippine Agr. For. 1914, **3**, 81.

[2] Philippine J. Sci. 1922, **20**, 363.

[3] Ibid. 1930, **41**, 85.

Changes in Composition During Ripening.—The formation of sugars from starch during ripening was established by early investigators employing chemical and microscopical methods. Corenwinder,[1] Ricciardi,[2] and Gerber[3] studied the nature of the sugars, Gerber's results on banana flesh, as summarized by E. M. Bailey,[4] being as follows:

	Invert sugar	Invert sugar + sucrose	Total carbohydrates
	%	%	%
Green	1.24	7.76	21.51
Green-yellow	1.24	7.76	21.51
Yellow	6.43	17.48	22.12
Yellow-brown	8.55	19.00	20.00
Yellow-brown	11.05	18.26	19.00
Brown	10.90	16.60	16.60

The following determinations made by Bailey in conjunction with autolysis experiments illustrate the changes in carbohydrates during ripening:

	Total carbohydrates	Soluble carbohydrates	Insoluble carbohydrates
	%	%	%
Green	26.56	1.30	25.26
Ripe	19.00	17.02	1.98

In Gerber's and Bailey's analyses the results were calculated as dextrose; in the following analyses by Yoshimura[5] they were calculated as invert sugar and reduced to the dry basis:

	Water (fresh basis)	Sugars, reducing	Sucrose	Sugars, total	Starch	Tannin
	%	%	%	%	%	%
Nov. 9	70.13	0.00	0.00	0.00	68.16	1.75
Nov. 16	70.31	5.55	14.92	20.47	47.51	1.71
Nov. 23	71.47	13.47	28.61	42.08	24.40	1.71
Nov. 30	70.72	19.83	30.12	49.95	14.48	1.67

[1] Compt. rend. 1863, **57**, 781; 1879, **88**, 293.

[2] Ibid. 1882, **95**, 393.

[3] Ann. sci. nat. 1896, ser. 8, p. 4.

[4] J. Biol. Chem. 1906, **1**, 355.

[5] Z. Unters. Nahr.-Genussm. 1911, **21** 406.

Gore[1] studied the changes in both peel and flesh. Respiration was found to be most active at the time when starch hydrolysis was most rapid. Pentosans decreased sharply in the flesh, but only slightly in the peel. A transfer of water from peel to flesh was noted throughout the experiment. The changes in the content of protein, fat, and ash were slight. Myers and Rose[2] noted a decrease in the ratio of peel to flesh during ripening. In general the carbohydrate changes were in accord with those of previous workers, but the sucrose, which reached 12.52 per cent after the sixth day, decreased to 11.1 per cent on the fifteenth day.

Bananas shipped from Formosa to Kyoto, Japan, examined by Kondo, Nakajima, and Suzuki[3] while still green ten days after picking, contained: 49.3 per cent of fruit flesh, with a water content of 71.21 per cent, and 50.7 per cent of peel. Analyses of the fruit flesh while green and after ripening, calculated to the dry basis, follow:

COMPOSITION OF FORMOSAN BANANAS (KONDO ET AL.)

	Protein	Sugars, reducing*	Sucrose*	Dextrin	Starch	Pectin	Fiber	Tannin	Ash
	%	%	%	%	%	%	%	%	%
Green...	6.46	0.87	0.24	0.00	63.77	1.32	1.22	0.35	3.23
Ripe....	5.81	38.84	6.16	0.48	14.89	1.21	1.08	0.38	3.30

* As dextrose.

Bourdouil[4] analyzed bananas at two-day intervals during twenty-seven days, corroborating the results of earlier investigators as to the change of starch into sugars. The starch decreased from 22.94 per cent at the start to 0.83 per cent after twenty-one days, and the sucrose reached 14.38 per cent after thirteen days, diminishing thereafter to 6.24 per cent at the end of the experiment when the fruit was quite soft. The amount of solids at the end was 7.04 per cent less than at the start. Pectin diminished from 1.93 to 0.87 per cent.

Dried Bananas, as well as the meal and flour prepared therefrom, differ radically in their starch and sugar content according as they are made from the ripe or the unripe fruit, as is well brought out by results obtained by Reich[1] on products of the variety Gros Michel. The same author analyzed products of other varieties including the finger banana.

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[1] J. Agr. Res. 1915, **3**, 187.

[2] J. Am. Med. Ass. 1917, **68**, 1022.

[3] Mem. Col. Agr. Kyoto Imp. Univ. 1928, **6**, 23.

[4] Bul. soc. chim. biol. 1929, **11**, 1130; Rev. bot. appl. agr. trop. 1931, **11**, 656.

COMPOSITION OF DRIED PULP AND PEEL OF GROS MICHEL BANANA (REICH)

	Water	Solids, insol.	Protein	Fat	Acids as malic	Sugars, reducing	Sucrose	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Unripe:										
Dried pulp										
Min....	15.14	75.56	3.94	0.67	....	2.06	....	71.74	2.20	2.84
Max...	15.40	76.31	4.34	0.67	....	2.34	....	74.02	2.40	3.12
Dried peel	6.60	75.61	5.69	5.92	0.92	3.87	....	40.28	10.10	11.43
Ripe:										
Dried pulp										
Min....	19.00	7.50	3.33	....	0.98	60.28	1.21	3.43	1.65	3.02
Max...	23.20	7.90	4.02	....	0.98	61.86	2.62	3.70	1.65	3.32
Dried peel	7.40	52.18	6.52	8.24	1.99	20.03	....	8.17	12.66	13.45

Phosphorus-Organic Compounds. *Phytin.*—In the fruit of *M. sapientum* var. *Lacatan*, var. *suaveolens*, and var. *grandis* Bagaoisan[2] reports respectively 5.11, 0.41, and 0.67 per cent, dry basis.

Colors.—In experiments by Von Loesecke,[3] *chlorophyl* $(a + b)$ ranged from 51.7 to 102.9 mg. per kilo of fresh peel in the unripe fruit, as discharged from the ship, and decreased to zero in four to five days. The yellow pigments, consisting of *xanthophyl* and *carotene*, remained practically constant throughout ripening. In the fresh peel, the xanthophyl ranged from 5.2 to 7.3 mg. per kilo, the carotene from 1.2 to 3.7 mg. per kilo.

Odorous Constituents.—It was early noted that the odor of the banana resembles that of amyl acetate. Kleber,[4] by steam distillation, secured a quantity of a volatile oil which was split up into acetic acid and amyl alcohol, thus demonstrating that *amyl acetate* is an actual constituent.

Enzymes.—E. M. Bailey[5] detected *amylase, sucrase, raffinase, protease, lipase,* and *peroxydase* during ripening but obtained no positive tests for maltase, dextrinase, or lactase.

[1] Loc. cit.

[2] Philippine Agr. 1932, **21,** 53.

[3] J. Am. Chem. Soc. 1929, **51,** 2439.

[4] Am. Perfumer 1913, **7,** 235.

[5] J. Am. Chem. Soc. 1912, **34,** 1706.

Nelson and Hemperly[1] discovered that banana pulp and expressed juice contain an activator for yeast apozymase. Although not affected by boiling for a few minutes, evaporation to dryness at pH 6.4 caused its destruction. The same authors also found *phosphatase* and *carboxylase.*

Mineral Constituents.—The table below gives analyses by Reich[2] of the crude ash of the Gros Michel variety, the sum of the constituents determined, subtracted from 100, being chiefly carbon dioxide. Analyses by Kondo, Nakajima, and Suzuki[3] of the ash of Formosan bananas, calculated free of carbon dioxide, are also included.

COMPOSITION OF BANANA ASH

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_3O_4	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Reich										
Unripe:										
Dried pulp	52.20	3.09	1.13	5.45	0.49	0.49	5.52	2.67	2.19	16.83
Dried peel.	54.15	2.38	1.30	2.49	....	....	2.84	3.86	4.56	14.08
Ripe:										
Dried pulp.	53.98	2.88	1.09	5.00	0.30	0.36	5.06	3.33	2.19	14.40
Dried peel.	52.23	2.72	1.24	2.17	....	....	2.59	4.52	5.44	14.60
K., N., and S.										
Fresh pulp...	39.47	27.18	1.56	12.12	0.70	....	9.60	2.58	3.61	3.19
Fresh peel...	64.90	14.80	3.78	3.86	0.65	....	3.50	1.50	5.63	1.21

Chace[4] reports partial analyses of the ash of the pulp of 3 varieties from Cuba:

	Ash in pulp	K_2O	CaO	MgO	P_2O_5	SO_3	Cl
	%	%	%	%	%	%	%
Niño..........	0.70	46.46	0.95	0.42	10.36	2.36	6.59
Oronoco.......	1.80	52.41	1.02	1.90	5.16	3.32	8.48
Colorado......	0.83	51.47	0.37	0.65	3.25	2.77	7.63

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[1] J. Amer. Chem. Soc. 1933, **55**, 1102.

[2] Loc. cit.

[3] Loc. cit.

[4] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

Attention is directed to the lack of agreement of the results on soda and chlorine by the foregoing authors. König[1] gives an analysis of the ash of the ripe pulp showing K_2O 52.64, Na_2O 2.76, CaO 1.17, MgO 5.36, Fe_2O_3 0.39, Mn_3O_4 0.58, P_2O_5 6.12, SO_3 3.45, SiO_2 2.33, and Cl 11.64 per cent.

An ash analysis of the pulp of the Dwarf or Fiji banana (*M. cavendeshii*) by Doherty[2] in the main corresponds with analyses by Reich of the common banana but the percentages of soda (12.00) and phosphoric acid (7.70) are higher and the percentage of chlorine (1.10) is lower.

In 10 varieties of bananas Martinez[3] obtained total ash 0.74 to 1.27, CaO 0.004 to 0.021, MgO 0.031 to 0.210, Fe_2O_3 0.003 to 0.018, and P_2O_5 0.109 to 0.294 per cent.

Minor Mineral Constituents. *Iron.*—Edible portion 8 mg. per kilo, fresh basis (Sherman).[4] Edible portion 17.6 mg. per kilo, fresh basis (Peterson and Elvehjem).[5] Edible portion, 2 samples, 3.5, 6.0, fresh basis (Toscani and Reznikoff).[6]

Aluminum.—Edible portion 1.4, skin 15 mg. per kilo, dry basis (Bertrand and Lévy).[7]

Copper.—Edible portion 2.2 mg. per kilo, fresh basis, 8.7 mg. per kilo, dry basis (Guérithault).[8] Edible portion 2.1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[9]

Zinc.—Edible portion 2.8 mg. per kilo, fresh basis (Bertrand and Benzon).[10]

Arsenic.—Edible portion 0.06 mg. per kilo, fresh basis (Jadin and Astruc.)[11]

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[1] Chem. mensch. Nahr.-Genussm., Berlin, 1920, **2**, 877.

[2] Chem. News 1892, **66**, 187.

[3] Philippine Agr. 1933, 21, 547.

[4] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] J. Nutrition 1934, **7**, 79.

[7] Compt. rend. 1931, **192**, 525.

[8] Ibid. 1920, **171**, 196.

[9] J. Biol. Chem. 1929, **82**, 465.

[10] Bul. soc. hyg. aliment. 1928, **16**, 457.

[11] Compt. rend. 1912, **155**, 291.

FRUITS OF THE MULBERRY FAMILY

(*Moraceæ*)

To this family belong the fig, the mulberries, the jack fruit, and the breadfruit, all monœcious or diœcious trees.

COMPARATIVE MACROSCOPIC STRUCTURE.—The numerous small apetalous *flowers* and the *fruits*, if such develop, are borne in dense spikes, except in the fig where they are on the inside of the receptacle. In none is the principal edible fruit tissue pericarp; in the fig it is receptacle, in the others perigone (calyx). The perigone of the mulberry consists of four lobes, of the jack fruit and breadfruit of tubes, more or less fleshy and consolidated.

COMPARATIVE MICROSCOPIC STRUCTURE.—The outstanding histological character is the presence in the fleshy parts of *latex tubes* with conspicuous grains. Except in members of the same genus, neither the pericarp nor the spermoderm shows noteworthy analogies. A sclerenchymatous endocarp occurs in the fig and mulberry, but the form of the cells is quite different. An endosperm is well developed in the fig and mulberry, but is absent in the jack fruit and breadfruit. Starch occurs in the cotyledons of the jack fruit and breadfruit; it is absent in the cotyledons of the fig and mulberry.

COMPARATIVE CHEMICAL COMPOSITION.—As regards the chief food constituent, there is a lack of uniformity; in the fig and mulberry it is *sugar*, in the jack fruit and breadfruit it is *starch*, although at full maturity much of the starch passes into sugar. None of the fruits has any considerable acidity. The seeds of both the jack fruit and the breadfruit are starchy.

FIG

Ficus Carica L.

Fr. Figue. Sp. Higo. It. Fico. Ger. Feige.

Since prehistoric times, the fig tree has grown wild in the Mediterranean region from Syria to the Canaries. Its early cultivation is attested by ancient art, history, and story. From its original home it was carried east first to India and then during the Middle Ages to China.

In colonial days the garden fig (var. *hortensis*) was introduced into subtropical America, and during the last half of the nineteenth century the Smyrna fig (var. *smyrniaca*) and the wild fig or caprifig (var. *sylvestris*), together with the insect that effects cross fertilization, were carried into California.

One type of garden fig has practically only " mule " (sterile) flowers yet it develops two crops of good-sized fruit, although of course seedless, without insect aid. Other types produce, without caprification, only one crop, either the first or the second, the crop failing when a large number of unfertilized female flowers are present.

In the inflorescence of the Smyrna fig the flowers are pistillate and require the pollen of the staminate flowers of the wild fig not only to ripen the nutty-flavored seeds for which they are famous but also to bring about full development of the receptacle or fleshy part of the fruit. This pollination is effected by the fig wasp (*Blastophaga grossorum*) that develops in a second kind of sterile flower (" gall " flower) of the wild fig which, since this variety does not produce edible fruits, serves merely to harbor the insect. Since early times, wild figs have been hung on the trees of the Smyrna fig so that the insect as it emerges may find a ready field for its activities, and it was not until this practice was copied in California that growing of figs of this type became successful.

Further details on the history, culture, curing, and varieties are given by Eisen.[1]

Throughout the Mediterranean region and further east the fig, both fresh and dried or preserved, is an important article of diet. Being one of the cheapest fruits, it is used to adulterate preserves and jams. In the United States it is more of a luxury, being used in various confections, biscuits, and pastries, as well as dried, canned, and preserved. A substitute for coffee is made from figs.

MACROSCOPIC STRUCTURE.—Unlike those of the breadfruit and mulberry, the numerous minute *flowers* are borne on the inside, instead of the outside, of a fleshy receptacle, and neither the perigone nor the pericarp contributes succulent tissues to the ripened fruit. The calyx lobes are small, pointed; the ovary is usually one-celled and one-ovuled.

The *fruit* (Fig. 167) at maturity shows a great diversity of colors in the different cultivated varieties—white, yellow, green, red, brown, blue, purple, and black. It is more or less pear-shaped with a large soft stem. About the small opening are small scales. The so-called " seeds " (drupelets) (Fig. 168) are nearly globular, about 2 mm. in diameter and hard like berry seeds because of the stony endocarp. The spermoderm is thin; the endosperm (*E*) and embryo (*Em*) about equal in volume, the latter being curved so that the tips of the cotyledons and the radicle nearly meet. Withered calyx lobes and abortive flowers may accompany the fruits.

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[1] U. S. Dept. Agr., Div. Pom. 1901, Bul. 9.

MICROSCOPIC STRUCTURE.—Writers on the histology of foods and drugs describe more or less in detail the structure of the fig, special stress being laid on its detection in coffee and coffee substitutes.

Receptacle.—Cross sections (Fig. 169) show that four layers are present, but some of the characters are best studied in surface view (Fig. 171): (1) *outer epiderm* (*epi*, *aep*) of polygonal cells with thickened outer walls, raised stomata (*sto*), unicellular (t^1)and multicellular (t^2) hairs; (2) *hypoderm* (*hy*) of rounded polygonal cells, some containing small oxalate crystal rosettes; (3) *fruit flesh* made up of large, loosely arranged parenchyma cells (*p*) containing large crystal rosettes (*cr*), branching latex tubes (*l*), and delicate fibro-vascular bundles; and (4) *inner epiderm* (*iep*) of more or less longitudinally elongated, somewhat porous, wavy-walled cells and unicellular hairs.

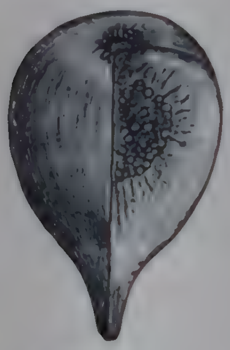

FIG. 167.

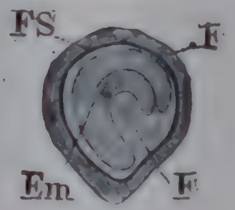

FIG. 168.

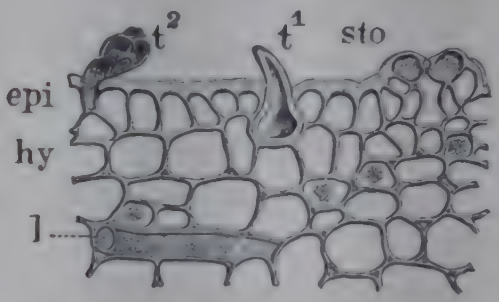

FIG. 169.

FIG. 167.—Fig. Multiple fruit. × ½. (K.B.W.)

FIG. 168.—Fig. Pericarp and seed in longitudinal section. *F* outer pericarp; *FS* inner pericarp and spermoderm; *E* endosperm; *Em* embryo. × 10. (K.B.W.)

FIG. 169.—Fig. Outer receptacle in cross section. *epi* epiderm with t^1 unicellular conical hair, t^2 multicellular capitate hair, and *sto* raised stoma; *hy* hypoderm; *l* latex tube. × 160. (K.B.W.)

The *unicellular hairs* of the outer epiderm are pointed and thick-walled, varying from short to long. On the otherwise characterless scales (*Sc*) about the opening of the receptacle, the hairs are short, narrow, and often without lumen except in the bulbous base.

The *latex tubes* are chiefly remarkable for their numbers.

Perigone.—This is an exceedingly delicate, thin-walled, characterless tissue.

Pericarp (Fig. 170, *F*; Fig. 172).—The fruits are studied with difficulty owing to their small size, the disorganization at maturity of middle tissues, and the brittle endocarp. Four distinct layers, however, may be demonstrated: (1) *epicarp* (*epi*) of radially elongated cells with mucilaginous thickening of the outer walls and often colored contents; (2) *mesocarp* (*mes*) of small, exceedingly delicate, porous cells, adhering closely to the next layer; (3) a single row of minute *stone cells* (*st*), each containing a single crystal; and (4) *endocarp* (*end*) of radially elongated stone cells with wavy walls.

Spermoderm (Fig. 170, *S*; Fig. 172).—The tissues are thin-walled and brown throughout and are differentiated only on treatment with sodium hydroxide or Labarraque solution. The cells of the *outer epiderm* (*aep*) are wavy-walled and more elongated than those of the *inner epiderm* (*iep*).

Endosperm (Figs. 170 and 172, *E*).—This consists of *aleurone cells* varying as to the number of rows, from a very few to many, according to the location.

Embryo (Fig. 170, *C*; Fig. 172, *Em*).—The cells are small, starch-free, and characterless.

CHIEF STRUCTURAL CHARACTERS.—Multiple fruit hollow with drupelets borne on inner surface of receptacle. Seed with endosperm and curved embryo.

Receptacle: outer and inner epiderm with hairs; fruit flesh with branching latex tubes and crystal rosettes. Pericarp: epicarp cells radially elongated, outer walls mucilaginous; endocarp of wavy-walled stone cells. Spermoderm characterless. Endosperm and embryo containing aleurone grains but no starch.

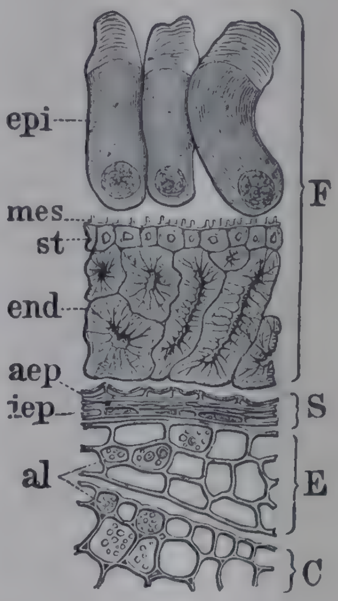

FIG. 170.—Fig. Pericarp and seed in cross section. *F* pericarp: *epi* epicarp, *mes* remains of mesocarp, *st* stone cell layer, *end* endocarp. *S* spermoderm: *aep* outer and *iep* inner epiderm. *E* endosperm and *C* cotyledon with *al* aleurone grains. ×160. (K.B.W.)

CHEMICAL COMPOSITION.—The most extensive work on the composition of fresh figs is that of Colby,[1] who analyzed 41 samples representing 29 varieties. Thompson[2] analyzed the edible portion constituting 78 to 82, aver. **80,** per cent of the whole fruit; Azadian,[3] the pulp (49.2 per cent) and the seeds (10.8 per cent) separately; and Paladino,[4] the pulp and seeds together and the skin of the fresh fruit, also the dried whole fruit. Atwater and Bryant[5] give 3 analyses of dried figs. See table page 511.

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[1] California Agr. Exp. Sta. Rep. 1893/4, pp. 225 and 271.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[3] Ann. fals. 1927, **20,** 464.

[4] Biochem. Z. 1910, **24,** 263.

[5] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

Fresh Magnolia figs, as analyzed by Traub and Fraps,[1] contained: dry matter 16.8, protein 0.7, lipoids 0.08, total sugars 11.8, reducing sugars 11.3, pentosans 1.02, fiber 1.0, and ash 0.4 per cent. These figures are in accord with those found by Guglielmi [2] and by Rossi,[3] who examined the dried figs.

Fatty Oil of Seed.—Determination of the values of oil extracted from the seeds, made by Azadian,[4] gave: specific gravity at 15° C. 0.9253 to 0.9493, aver. **0.9351**; refractive index at 40° C. 1.4670 to 1.4725, aver. **1.4689**; saponification number 193 to 205, aver. **196.9**; iodine number 102.8 to 117.4, aver. **111.0**; and acid number (recalculated) 1.7 to 3.4, aver. 2. Jamieson and McKinney [5] report for the seed oil of caprified figs (containing water 6.3 and oil 30.44 per cent): refractive index at 25° C. 1.4775, saponification number 190.1, iodine number 169.4, thiocyanogen number 108.4, acid number 0.87, acetyl number 6.1, unsaponifiable matter 1.07 per cent, also glycerides of fatty acids as follows, oleic 19.8, linolic 35.1, linolenic 34.2, palmitic 5.5, stearic 2.3, and arachidic 1.1 per cent.

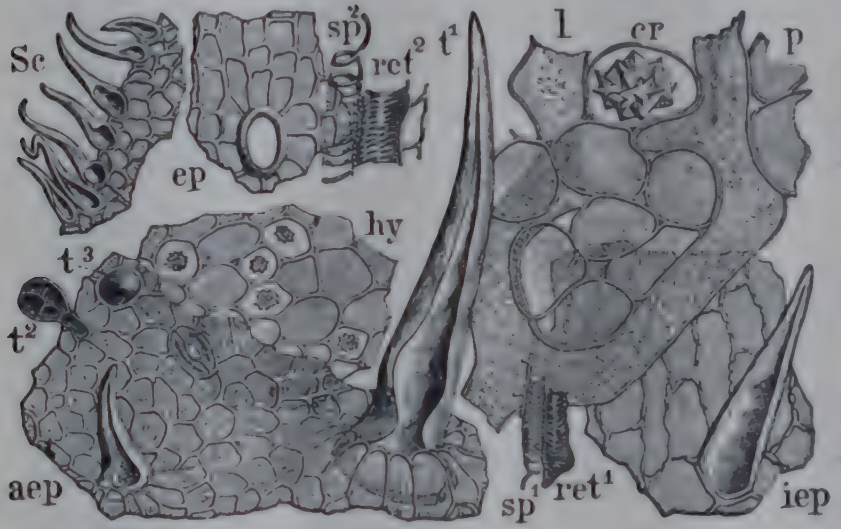

Fig. 171.

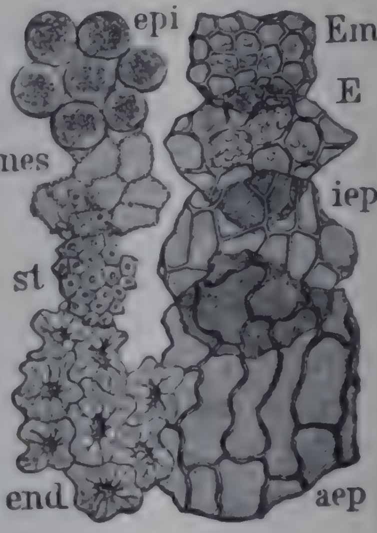

Fig. 172.

Fig. 171.—Fig. Elements of receptacle ("fruit") in surface view. *aep* outer epiderm with stoma, t^1 long and t^3 short conical unicellular hair, and t^2 multicellular capitate hair; *hy* hypoderm with small crystal rosettes; *p* parenchyma of fruit flesh with *cr* large crystal rosette; *l* branching latex tube; sp^1 spiral and ret^1 reticulated vessels; *iep* inner epiderm with hair (seen from below); *Sc* edge of scale at opening with hairs; *ep* epiderm with hair scar, sp^2 spiral and ret^2 reticulated vessels of edible stem-like base. × 160. (K.B.W.)

Fig. 172.—Fig. Elements of fruit ("seed") in surface view. Pericarp: *epi* epicarp, *mes* remains of mesocarp, *st* stone cell layer, *end* endocarp. Spermoderm: *aep* outer and *iep* inner epiderm. *E* endosperm. *Em* embryo. × 160. (K.B.W.)

Acids.—In dried Adriatic figs Nelson[6] found *citric* and *acetic acids.*

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[1] Proc. Am. Soc. Hort. Sci. 1928, p. 306.

[2] Bol. Aboz. Ital. 1908, **4**, 23.

[3] Ibid. 1912, **7**, 51.

[4] Loc. cit.

[5] Oil and Soap 1935, **12**, No. 5, 88.

[6] J. Am. Chem. Soc. 1928, **50**, 2012.

COMPOSITION OF FIG.

	Samples	Solids, total	Solids, insol.	Protein	Fat	N-f. ext.	Acids as citric	Sugars	Fiber	Ash
		%	%	%	%	%	%	%	%	%
Colby (U. S.)										
Whole:	41									
Min.		11.46	....	0.73	....	.....	0.10	8.00	.....	0.36
Max.		38.84	....	2.59	....	.....	0.42	20.99	.....	1.16
Aver.		**20.13**	....	**1.34**	....	.....	**0.17**	**15.51**	.....	**0.58**
Thompson (Hawaii)										
Edible portion:	3									
Min.		10.27	2.09	0.99	0.21	6.52	0.18	6.28*	1.07	0.45
Max.		17.72	2.85	1.96	0.37	14.56	0.24	13.14*	1.28	0.55
Aver.		**14.98**	**2.37**	**1.40**	**0.28**	**11.64**	**0.21**	**10.80***	**1.17**	**0.49**
A. and B. (U. S.)										
Dried:	3									
Min.		75.0	....	2.6	0.3	68.3†	....	.....	.....	2.2
Max.		88.4	....	5.7	0.3	83.1†	....	.....	.....	2.5
Aver.		**81.2**	....	**4.3**	**0.3**	**74.2**†	**0.57**‡	.....	.....	**2.4**
Paladino (Italy)										
Pulp and seeds	1	20.00	....	0.70	0.30	17.00§	....	16.20	1.30	0.70
Skin	1	14.00	....	0.00	0.10	5.62§	....	5.40	5.76	....
Whole, dried	1	43.00	....	4.10	2.20	26.18§	....	26.06	8.00	2.52
Azadian (Egypt)										
Pulp:	9									
Min.		8.66	....	0.20	....	.....	0.03	8.05	.....	0.28
Max.		12.36	....	0.70	....	.....	0.81	10.22	.....	0.73
Aver.		**10.73**	....	**0.47**	....	.....	**0.23**	**9.00**	.....	**0.41**
Seeds	1	6.00	....	....	**5.80**‖	28.12¶	....	.....	55.60	1.71

* Sucrose 0.00 to 0.39, aver. **0.13**%. † Includes fiber. ‡ 1 sample. § Gum and mucilage 0.80, 2.74, and 0.18%. ‖ Resin 1.70%. ¶ Starch.

As compared with the normal fruit, " black neck " (acid) figs contained less citric but ten times as much acetic acid. Normal Calimyrna figs contained citric acid 0.35 per cent, free acetic acid 0.026 per cent, and a small amount of *malic acid.* Fruit of the same variety affected with internal rot contained citric acid 0.33 and free acetic acid 0.056 per cent. Arbenz [1] found 0.12 per cent, and Viehoever, Kunke, and Mastin [2] 0.21 per cent of *oxalic acid* in dried figs.

Enzymes.—Gerber [3] has proved that the *lipase* and *diastase* of fig latex are respectively only one-twelfth and one-eighth as active as those of the paper mulberry; the *protease* on the other hand is 100 times as active as the corresponding enzyme of the paper mulberry and differs further in coagulating boiled milk more readily than raw.

Deleanu [4] has shown that the peptolytic enzyme of the fig and the papaya are identical. The studies which he carried out on the proteins of the leaves have a bearing also on the protein of the two fruits.

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[1] Mitt. Lebensm. Hyg. 1917, **8**, 98.

[2] Science 1917, **46**, 564.

[3] Bul. soc. bot. France 1912, [4] **2**, mem. 23.

[4] Bul. sec. sci. acad. roumain 1916, **4**, 345.

Mineral Constituents.—Results by Jaffa and Colby[1] on ash and ash constituents in White Adriatic figs, calculated to the fresh fruit, follow:

Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
% 0.897	% 0.54	% 0.01	% 0.08	% 0.05	% 0.01	% 0.002	% 0.10	% 0.04	% 0.04	% 0.02

A partial analysis of Smyrna figs gave, on the ash basis, only four-fifths as much potash but about the same amount of phosphoric acid as in the White Adriatic.

Minor Mineral Constituents. *Iron.*—Dried figs 30 mg. per kilo, as sold (Häusermann).[2] Dried figs 39.6 mg. per kilo, as sold (Peterson and Elvehjem).[3]

Copper.—Dried figs 3.5 mg. per kilo, as sold (Lindow, Elvehjem, and Peterson).[4]

Zinc.—Whole fresh violet figs 1.2 mg. per kilo, fresh basis; whole dried Smyrna figs 3.6 mg. per kilo, fresh basis (Bertrand and Benzon).[5]

MULBERRY

Morus spp.

Fr. Mûre. Sp. Mora. It. Mora. Ger. Maulbeere.

Leaves of *M. alba* L. are the best food for silkworms. Cultivation of the tree for this purpose in China antedates history. From China and India its cultivation spread westward although it appears that the leaves of the black mulberry (*M. nigra* L.), a tree grown more for its fruit, was first used in Europe as silkworm food. Strange to say, in the United States where the silkworm culture has been abandoned, it is varieties of white mulberry which, according to Bailey,[6] have been more commonly developed for food—at least in the northern and eastern sections.

The Chinese species (*M. multicaulis* Perr.), considered by many botanists a variety of *M. alba*, was introduced into the United States when attempts were made to establish the silkworm industry there, but is now no longer important.

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[1] California Agr. Exp. Sta. 1893, Bul. **102**.

[2] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Ibid. 1929, **82**, 465.

[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

[6] Cornell Exp. Sta. Bul. 1892, Bul. **46**.

MACROSCOPIC STRUCTURE.—The mulberries are monœcious or diœcious trees, the *flowers* being borne in short spikes. The female flower is characterized by the two-celled ovary developing into a one-celled drupelet free from, but closely invested by, the perigone of four fleshy calyx lobes. Numerous drupelets with investing perigone are closely crowded together forming a multiple *fruit* resembling the blackberry (an aggregate fruit) in general form, size, and, in the case of dark varieties, color, but not in structure. The pericarp, although succulent, contributes little to the bulk. Commonly only a few of the drupelets are perfect with a well-developed hard endocarp and fertile seed corresponding to the stone of a peach. Each of the small stones contains a single *seed*. The curved embryo is embedded in the endosperm. Peduncle, rachis, sepals, pericarp, and seed are all present in the fruit as it drops from the tree.

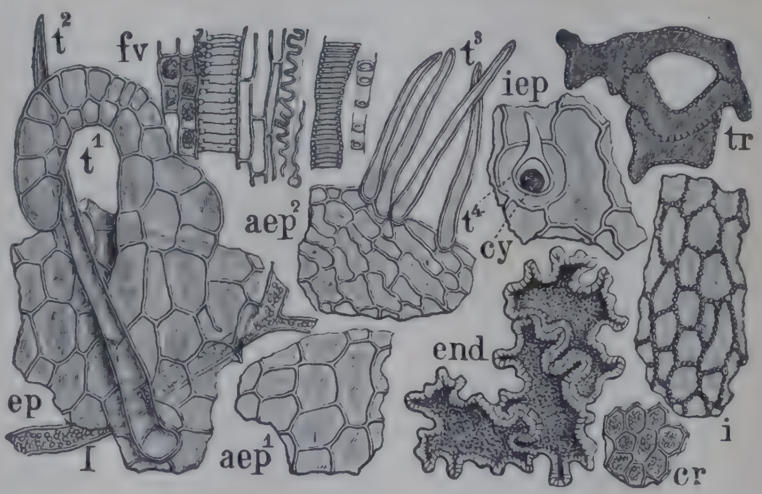

FIG. 173.—White Mulberry. Elements in surface view. Rachis: *ep* epiderm with t^1 unicellular and t^2 multicellular hairs, *l* latex tube, *fv* fibro-vascular bundle with spiral and annular vessels and crystal fibers. Calyx: aep^1 outer epiderm on body, aep^2 at tip with t^3 hairs, *iep* inner epiderm with t^4 hair containing *cy* cystolith. Pericarp: *cr* crystal cells of inner mesocarp, *end* endocarp. Spermoderm: *tr* cross cells of spongy parenchyma, *i* inner epiderm. × 160. (A.L.W.)

MICROSCOPIC STRUCTURE (Fig. 173).

Peduncle.—The *epiderm* is characterless except for the hairs which are partly short and stiff and partly long and thin-walled. Numerous crystal fibers, with crystal masses showing several edges rather than points, accompany the fibro-vascular bundles. The vessels and hairs are the only strongly lignified elements. Bast fibers are absent.

Rachis.—Three forms of hairs occur on the *epiderm* (*ep*): (1) multicellular, hook-shaped (t^2), (2) long, thin-walled (t^1), and (3) short, stiff, dagger- or scimitar-shaped. The *cortex* contains fibro-vascular bundles (*fv*) and accompanying crystal fibers like those of the peduncle, also branching latex tubes (*l*).

Perigone.—On the body of the calyx lobes, the *outer epiderm* (aep^1) is made up of polygonal, isodiametric or somewhat elongated cells, often in longitudinal rows; at the apex, of narrow cells (aep^2), often with wavy walls and long, blunt-pointed hairs (t^3). The *mesophyl* consists of ground parenchyma with numerous branching latex tubes. The latex grains reach or exceed 5 μ. In the nerves are fibro-vascular bundles like those in the peduncle and rachis. The *inner epiderm* (*iep*) is characterized by the long wavy-walled cells and especially by the short curved hairs (t^4) each with a cystolith (*cy*) of calcium carbonate in its base.

Pericarp.—The *epicarp* is much like the outer epiderm of the perigone, but lacks hairs. The *mesocarp* is also similar in its outer layers but has a layer of small *crystal cells* (*cr*) adjoining the endocarp. Each cell of this crystal layer fits into a depression in the next layer, the crystal rosettes being as described above. This layer is evident even in the abortive drupelets. The *endocarp* (*end*), consisting of a single layer of deeply sinuous-walled sclerenchyma cells with numerous pores, is the most conspicuous tissue of the whole fruit.

Spermoderm.—The *outer epiderm* is not easily found, but the *inner epiderm* (*i*) is conspicuous because of the beaded walls. Soaking in dilute sodium hydroxide or warming with chloral hydrate brings out the brown beaded, usually transversely elongated, cells of the *middle layer* (*tr*) and intercellular spaces.

Endosperm and **Embryo** contain rounded aleurone grains, up to 9 μ, which appear to contain crystalloids but no globoids.

CHIEF STRUCTURAL CHARACTERS.—Fruit blackberry-like; calyx lobes fleshy, enclosing drupelets.

Peduncle, rachis, and perigone with hairs, hooked-shaped, multicellular forms of rachis characteristic; rachis and perigone characterized by branching latex tubes and crystal fibers; inner epiderm of perigone bearing cystolith hairs; endocarp sclerenchymatous, sinuous-walled. Endosperm and embryo containing aleurone grains.

CHEMICAL COMPOSITION.—An early analysis of the black mulberry by Fresenius[1] gave: water 84.71, protein 0.36, acid as malic 1.86, invert sugar 9.19, pectin 2.03, and ash 0.57 per cent.

The range in composition of the pulp of 5 samples of Austrian mulberries, reported by Hotter,[2] follows:

COMPOSITION OF MULBERRIES (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Min.....	15.7	3.2	10.0	0.4	4.6	2.0	2.7	0.4	0.06	0.85
Max.....	18.4	7.0	17.4	0.9	14.1	8.4	6.0	0.8	0.16	0.94

* As invert. † Phosphoric acid 0.10 to 0.13%.

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[1] Ann. Chem. Pharm. 1854, **101**, 219.

[2] Z. Landw. Versuchsw. 1906, **9**, 747.

Color.—Yamamoto[1] identified the anthocyanin *chrysanthemin* which on hydrolysis yielded one molecule each of cyanidin and dextrose.

JACK FRUIT

Artocarpus integrifolia Forst. = *A. integra* L.

Fr. Jacque. Sp. Jak. Port. Jaca. Ger. Jackfrucht.

Disregarding the exaggerated reports of enthusiastic travelers, the jack fruit is doubtless the largest of fruits, individuals weighing as much as 20 kilos. It is indeed fortunate that such heavy bodies are borne on the main trunk or main branches of the tree. De Candolle traces the origin of the tree to India. Its cultivation is now found in India, Ceylon, Malaysia including the Philippines, Brazil, and other tropical regions.

The fruit pulp is eaten raw, cooked in various ways, and preserved, but it is not highly esteemed by Europeans. Of better repute are the starchy seeds which, roasted, resemble chestnuts in nutritive value and flavor.

MACROSCOPIC STRUCTURE.—The very small, apetalous *flowers* of both sexes are borne separately in dense heads. Most of the ovules of the one-celled, one-ovuled ovary fail to develop into seeds. In the *multiple fruit* the outer ends of the perigones (calyx tubes) of the individual flowers are grown together forming an elongated rounded mass covered with small cones. On cutting through the flesh to the axis (Fig. 174) the perigones are seen to be consolidated (P^3) only for about one-third the distance, while for the remaining two-thirds they are free, those with pericarp and seed being tubular and fleshy (P^1), the remainder, development of which was arrested, strap-shaped and narrow (P^2).

The bean-shaped *fruit* proper is about 3 cm. long. Attached to one edge, two-thirds of the distance to the outer end, are the remains of the long style. The pericarp (F) forms a leathery skin within which is a thin aril, resembling the skin of an egg, enclosing the anatropous *seed* (S), with a thin spermoderm and fleshy cotyledons, but without endosperm.

MICROSCOPIC STRUCTURE.—The **Outer Perigone Tissues** (Fig. 175), formed by the consolidation of the outer portions of the perigones, consist of (1) *epiderm* (*aep*) of rounded cells with thick-walled hairs (t), sunken at the base, and stomata, and (2) *fruit pulp* of porous, thick-walled spongy parenchyma (p), forming the ground tissue, through which are distributed branching latex tubes (l) and bundles of broad, thick-walled fibers (f).

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[1] J. Agr. Chem. Soc. Japan 1934, **10**, 1046.

The **Inner Perigone Tissues** (Fig. 176, P) are thicker when they belong with a fully developed pericarp and seed than in the flattened bands representing the perigones of the abortive fruits, but not essentially different in structure. The layers are as follows: (1) *outer epiderm* of longitudinally elongated cells, arranged end to end in rows, with thickened outer walls; (2) *mesophyl* of rounded starch parenchyma cells (am^1), latex tubes (l^1), longitudinally arranged, and occasional weak fibro-vascular bundles; and (3) *inner epiderm* of longitudinally elongated cells differing from those of the outer epiderm in that the walls are porous and the arrangement is not end to end.

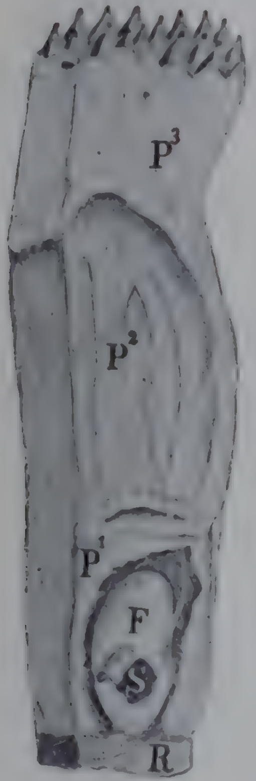

FIG. 174.

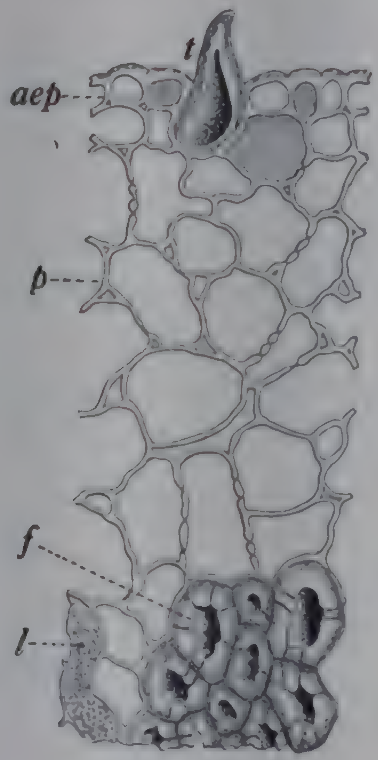

FIG. 175.

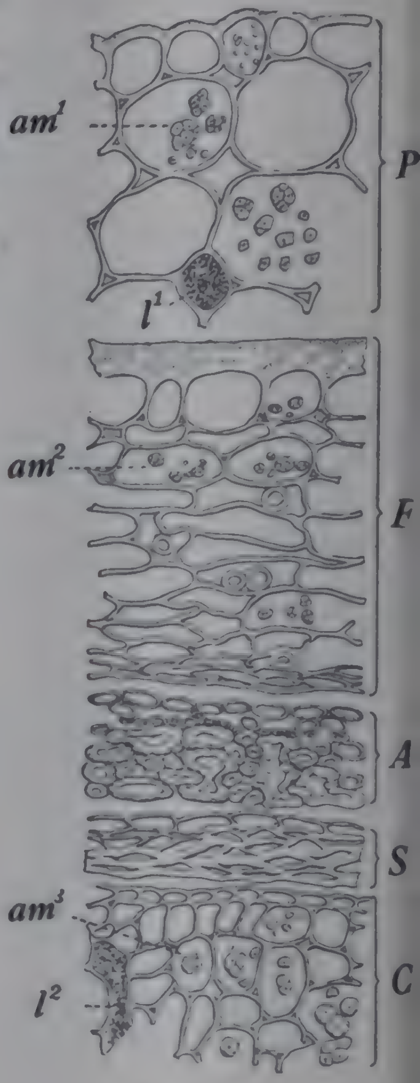

FIG. 176.

FIG. 174.—Jack Fruit. Multiple fruit in cross section. R receptacle; P^1 inner portion of developed perigone; P^2 inner portions of abortive perigones; P^3 consolidated outer portions of perigones ending in cones on the surface; F pericarp with style arising from one side; S seed. × ½. (A.L.W.)

FIG. 175.—Jack Fruit. Multiple fruit in cross section showing outer consolidated perigone tissues. aep outer epiderm with t hair; p spongy parenchyma; f fiber bundle; l latex tube. × 160. (K.B.W.)

FIG. 176.—Jack Fruit. Perigone (inner free portion), fruit, and seed in cross section. P perigone: am^1 starch parenchyma, l^1 latex tube. F pericarp: am^2 spongy starch parenchyma. A aril. S spermoderm. C cotyledon: am^3 starch parenchyma, l^2 latex tube. × 160. (K.B.W.)

The individual *starch grains* are angular or truncated, up to 11 μ, with central hilum. They are densely packed in the cells of the mature perigone and occur mostly in small aggregates.

Pericarp (Fig. 176, *F*).—Three layers are present: (1) *epicarp* of polygonal cells characterized by the great thickening of the outer walls as seen in cross section; (2) *mesocarp* of tangentially elongated, in surface view distinctly porous, spongy, starch parenchyma cells (am^2), through which run very delicate fibro-vascular bundles; and (3) *endocarp* of collapsed cells.

The color of the pericarp is due to transparent brown contents. The *starch grains* are small and occur in small aggregates up to 11 μ.

Aril (Fig. 176, *A*).—In the outer part the cells are small, thin-walled and loosely arranged, in the inner part larger, thick-walled, porous, and often irregular in shape. Throughout the tissues are colorless.

Spermoderm (Fig. 176, *S*).—The cells are collapsed and form a brown, nearly structureless band, the *outer epiderm* being distinguished by its darker color.

Embryo.—The cotyledons (Fig. 176, *C*) have a ground tissue of isodiametric cells containing *starch grains* (am^3), up to 15 μ, in small aggregates. Occasional *latex tubes* (l^2) are also present.

Chief Structural Characters.—Fruit muricate with outer portions of perigones consolidated, inner portions free and, when pericarp and seed are developed, fleshy; fruit proper bean-shaped with style on edge; pericarp thin; aril membranous; spermoderm thin; embryo fleshy, straight.

Starch present in inner perigone tissues, mesocarp, and cotyledons. Latex tubes occur in outer and inner perigone and cotyledons.

CHEMICAL COMPOSITION.—Analyses by Pratt and Del Rosario[1] and by Thompson[2] follow:

Composition of Edible Parts of Jack Fruit

	Edible	Solids, total	Solids, insol.	Protein	Fat	Acids as malic	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
P. and Del R.:											
Pulp.......	25	34.4	3.1	0.42	....	0.19	8.28	13.92	....	1.23	129
Thompson:											
Whole......	58	18.92	8.86	1.69	0.60	0.25	5.55	2.18	1.90	0.96	...
Pulp.......	32	23.20	5.76	1.44	0.45	0.38	6.51	8.64	1.31	0.93	...
Seeds......	87	50.82	34.94†	5.44	0.24	0.22	0.71	1.16	1.61	3.50	...

* Cc. *N*/10 acid per 100 grams fruit. † Hydrolyzable carbohydrates 23.53%.

The insoluble solids of the seeds consisted largely of starch.

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[1] Philippine J. Sci. 1913, **8**, 59.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

BREADFRUIT

Artocarpus communis Forst. = *A. incisa* L.

Fr. Fruit à pain. Sp. Fruto del pan. Port. Fruita pão.
It. Frutto del pane. Ger. Brodfrucht.

Originally, according to De Candolle, the breadfruit grew in the Sunda Islands whence it was introduced into other islands of Malaysia and Polynesia. Today in many of the islands it is the " staff of life " of the natives. In the western hemisphere it never has been of great importance except perhaps in Hawaii.

The seeded variety, like the jack fruit, is valuable chiefly for the seeds which resemble chestnuts in composition and flavor. Of much greater value is the seedless breadfruit. Safford[1] describes the primitive method of cooking in holes in the ground with hot stones, but adds that now the fruit is commonly boiled, baked, and fried like other vegetables. It is also sliced, dried, ground, and made into a kind of biscuit known as *madrai*, or a dough is prepared from the moist fresh pulp, allowed to ferment in the ground, and then used for cakes called *mahe*.

MACROSCOPIC STRUCTURE.—Neither *flower* nor *fruit* differs essentially in morphology from that of the jack fruit. In both, the height of the conical murications or terminals of the perigones show some variation, the greater variation occurring in the seedless breadfruit of which more varieties have been developed. In the outer half of the multiple fruit of the seedless form the flesh is solid, in the inner half somewhat porous, owing to the radially elongated cavities of the perigones, appearing like worm holes, but, unlike those of the jack fruit, the individual perigones are consolidated even in the inner half and, although containing only abortive flowers, are uniformly thickened.

MICROSCOPIC STRUCTURE OF SEEDED FRUIT.—The structure differs from that of the jack fruit only in unimportant details. In both species the percentage of starch in the whole fruit, as well as the relative amount in the outer and inner tissues, varies with the degree of ripeness and the variety. The size and form of the starch grains (Fig. 27, Plate III, Vol. I) also show considerable variation comparable with those of the starch of roots and tubers which, like the breadfruit, are used at different stages of ripeness.

Oxalate rosettes are stated to occur in the ground tissue, and hairs on the *inner epiderm* of the perigone, of seeded as well as seedless bread fruit, but neither was noted in specimens of jack fruit examined. In the structure of the pericarp and seed, no essential difference in the two species is apparent, the starch grains being indistinguishable under the microscope.

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[1] Useful Plants of Guam, Contrib. Nat. Herb. 1905, 9.

MICROSCOPIC STRUCTURE OF SEEDLESS FRUIT. Receptacle.—The central core, resembling that of the pineapple, contains strongly developed *fibro-vascular bundles* made up of large (often over 100 μ wide) spiral and spirally reticulated vessels and sieve tubes (up to 30 μ wide) with sieve plates evident without special treatment. *Crystal rosettes* occur near the bundles.

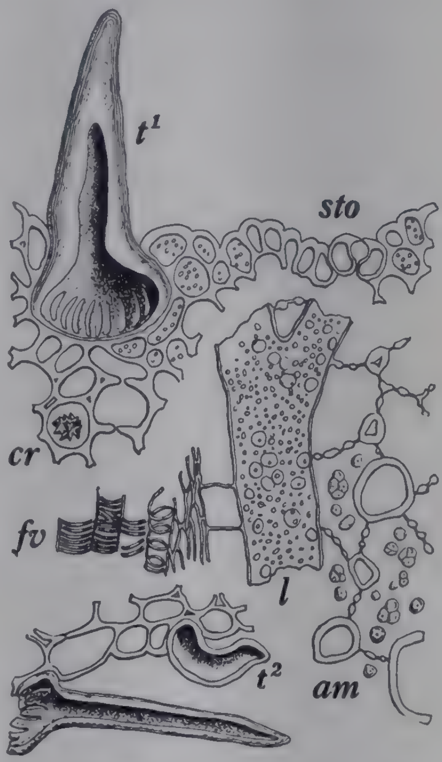

Fig. 177.—Seedless Breadfruit. Fruit (consolidated perigones) in cross section. Outer epiderm with t^1 hair and *sto* stoma; *cr* crystal cell; *fv* fibro-vascular bundle; *l* latex tube; *am* spongy starch parenchyma; inner epiderm with t^2 hairs. × 160. (K.B.W.)

Perigone (Fig. 177).—The tissues are (1) *outer epiderm* with stomata (*sto*) and thick-walled sunken hairs (t^1); (2) *mesophyl* of thick-walled, porous ground tissue becoming spongy inward, containing starch grains (*am*), up to 11 μ, and occasional oxalate rosettes (*cr*), also branching latex tubes (*l*), containing grains up to 15 μ, and fibro-vascular bundles (*fv*) with smaller elements than in the receptacle; and (3) *inner epiderm* of somewhat elongated cells, stomata, and thick- and thin-walled hairs (t^2).

The *starch grains* do not noticeably differ from those of the jack fruit, but the latex grains are larger, reaching 15 μ. As noted above, allowance must be made for stage of development and cultivated variety.

The thick-walled *hairs* of both epiderms are stiff, blunt-pointed, and have slit-pores about the base. In addition, thinner-walled hairs both short (t^2) and long (up to 400 μ) occur on the inner epiderm.

Chief Structural Characters.—Fruit multiple, muricate; perigones in seedless variety consolidated throughout, solid in outer half, with cavities in inner half containing abortive flowers.

Outer and inner epiderms with thick-walled hairs; mesophyl consisting of starch parenchyma (grains up to 11 μ), branching latex tubes (grains up to 15 μ), oxalate cells, and fibro-vascular bundles. Pericarp and seed, when present, as in jack fruit.

CHEMICAL COMPOSITION.—A single analysis by Pairault,[1] of breadfruit from the Antilles, and analyses by Thompson,[2] of the edible part of 2 varieties grown in Hawaii, follow:

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[1] Bul. ass. chim. sucr. dist. 1900–1901, No. 1, 77.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

COMPOSITION OF BREADFRUIT

	Edible	Solids, total	Solids, insol.	Protein	Fat	N-f. ext.	Acids as malic	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
Pairault:											
Antilles...	..	53.79	.....	2.34	0.40	45.07*	....	....	....	4.20	1.78
Thompson:											
Hawaiian.	78	41.82	20.35	1.58	0.19	37.90	0.07	1.75	7.74	1.20	0.95
Samoan..	83	26.89	8.44	1.58	0.52	22.66	0.11	4.93	9.67	0.98	1.15

* Starch 41.42%.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[1] reports 0.75 per cent, dry basis, in the flesh.

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[1] Philippine Agr. 1932, **21**, 53.

FRUITS OF THE BARBERRY FAMILY

(*Berberidaceæ*)

One species, the common barberry, is described below.

BARBERRY

Berberis vulgaris L.

Fr. Épine-vinette. Sp. Berberis. It. Barbero.
Ger. Berberisbeere.

Common barberry, an Asiatic and European shrub, has run wild in the United States. In wheat-growing sections it is regarded as an outlaw because it is the host for one stage of the wheat rust.

Barberry jelly is highly esteemed by those familiar with it but as a rule the shrub or one of its varieties is regarded merely as an ornamental and the fruit goes to waste.

MACROSCOPIC STRUCTURE.—Among the characters of the *flower* are the six small sepals, the six somewhat larger concave yellow petals, and the six stamens which, when released, snap toward the central stigma.

Several oblong, bright red *berries*, up to 12 mm. long, are in a cluster (raceme) on stems about the length of the berry. Unlike that of the much-grown Japanese species (*B. Thunbergii* DC.), the berry is dull, not lustrous. One to three anatropous peg-like *seeds*, up to 6 mm. long, arise from the base of the fruit cavity. The spermoderm is leathery; the endosperm is bulky; the embryo embedded in the axis of the endosperm is straight, elongated, with narrow cotyledons about the length of the radicle.

MICROSCOPIC STRUCTURE.—Pammel, Burnip, and Thomas[1] describe and picture the histology of the seeds (but not the fruits) of eight species of *Berberis*, including *B. vulgaris*, as seen in cross section, and give references to other papers.

Pericarp.—There are no striking tissues. The polygonal cells of the *epicarp* differ from those of the *endocarp* in being smaller and having red contents.

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[1] Iowa Acad. Sci. 1897, **5**, 11.

Spermoderm.—Five layers are clearly seen in cross section: (1) *outer epiderm* of radially much elongated cells, the outer walls of which have three lamellæ, the middle and inner being brown; (2) brown *parenchyma cells* diminishing in size inward; (3) triangular or spool-shaped *sclerenchyma cells* with intercellular spaces; (4) brown *tabular cells* with cuticularized outer and inner walls; and (5) colorless *compressed cells* (perisperm?).

Endosperm.—Typical *aleurone cells* make up the bulky endosperm. The aleurone grains reach a maximum of 15 μ in the inner layers. Owing to their close packing in the cells, they are polygonal in form. Although Arthur Meyer[1] states that crystalloids are absent, they appear to be present.

Embryo.—The cells are small and contain small aleurone grains.

Chief Structural Characters.—Fruit oblong, red, dull; seed shoepeg-like. Embryo axial in bulky endosperm.

Epicarp and endocarp cells polygonal; other fruit tissues characterless. Spermoderm with five coats, the third being of triangular or spool-shaped sclerenchyma cells. Endosperm and embryo containing aleurone grains.

CHEMICAL COMPOSITION.—Moeller,[2] on the authority of Lensen, states that the fruit contains malic acid 6.62 and sugars 3.57 per cent, but no acetic acid.

Alkaloids.—From *B. darwinii*, Cromwell[3] isolated an alkaloid, *berberine*, formed by decomposition of proteins in the presence of sugar residues.

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[1] Pflanzenpulver. Jena, 1901, p. 40.

[2] Real-Enzykl. ges. Pharm. Berlin, 2. Aufl. 1904, **2**, 662.

[3] Biochem. J. 1933, **27**, 860.

FRUITS OF THE CUSTARD-APPLE FAMILY

(*Annonaceæ*)

WITH the exception of *Asimina triloba*, the custard-apple or papaw of central and eastern United States, the family is confined to the tropics and sub-tropics. A few of the numerous species of *Annona* are extensively cultivated for their delicious fruits. The name custard-apple is applied to various species.

The fruits are eaten for dessert and serve for the preparation of sherbets, soda-water syrups, and preserves. Some of the species ship well and should be better known. The botanical characters of the genus *Annona* and the individual species are fully treated by Safford.[1]

The fruits of *Asimina* and six species of *Annona* are here described.

COMPARATIVE MACROSCOPIC STRUCTURE. *Flower.*—There are three outer and three smaller inner petals with numerous stamens and pistils crowded on a fleshy receptacle.

The *fruit*, varying in size, is an elongated berry in *Asimina* and a syncarp with more or less coherent carpels in *Annona*. In form the fruits of *Annona* vary from round to irregularly heart-shaped. The pericarp of *Asimina* has a thin skin and that of species of *Annona* a firm rind, but the edible fruit flesh of both is soft. On the surface of the syncarp, each carpel may be raised to a conical point or the whole fruit may be smooth with scarcely any line of demarcation between the individual carpels.

The *seed* is anatropous, brown, more or less flattened, elongated, varying somewhat in size. The thin leathery spermoderm fits into the deep clefts of the bulky endosperm. A small straight embryo is near the hilum.

COMPARATIVE MICROSCOPIC STRUCTURE.—The **Rachis** or core of the syncarp consists of tissues similar to those of the mesocarp, but the vascular bundles are more strongly developed.

Pericarp.—Five distinct tissues, not including the vascular bundles, constitute the fruit. The first three, namely, (1) *epicarp*, (2) *hypoderm*, and (3) *outer mesocarp* with stone cell groups, form well-marked zones, while the remaining two, namely, (4) *inner mesocarp* and (5) thin

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[1] Bailey: Stand. Cycl. Hort., New York, 1922; Popenoe: Manual Trop. Subtrop. Fruits, New York, 1920.

endocarp, are concentric with the individual seed cavities. Between the carpels of the syncarp the first three tissues are not developed.

Spermoderm.—This consists largely of a dense tissue of thick-walled *sclerenchyma cells*, those of the outer part being mostly longitudinally elongated while those of the inner part are transversely elongated. Monoclinic crystals are present in the subepiderm of the sweetsop, bullock's heart, and ilama.

Perisperm.—This in most species consists of a very thin layer of compressed cells. Here and there occur large *secretion cells* protruding into the endosperm and at first glance apparently belonging to it; Voigt,[1] however, concludes that they are a part of the perisperm.

Endosperm.—Rounded porous cells containing small aleurone grains make up the bulky endosperm.

COMPARATIVE CHEMICAL COMPOSITION.—Proximate analyses show that the solids consist chiefly of *sugars*, reducing sugar predominating. The acidity varies and its chemical nature is uncertain.

PAPAW

Asimina triloba Dunal

Fr. Asimine. It. Papaja. Ger. Pappaw.

The papaw or custard-apple, a native of central and eastern United States, is the fruit of a small tree often forming thick growths in the Mississippi Valley.

MACROSCOPIC STRUCTURE.—The *flower* has three large outer and three small inner purple petals, a few pistils, and numerous stamens. The *fruit* is an obliquely attached berry with a nearly black skin and soft yellow flesh when ripe. It varies from more or less cylindrical to sickle-shaped, up to 15 cm. long, with several flattened, ovate, shiny brown, horizontally arranged *seeds*, about 2.5 cm. long.

Some of the systematic botanies record the presence of an aril. The whitish inner mesocarp tissues immediately surrounding the seed, which remain firm after the pulp proper has broken down during ripening, do suggest an aril, but sections of the immature fruit fail to show any separation from the outer mesocarp. A similar tissue occurs in the kaki.

Longitudinal sections of the seed show the ruminating endosperm with brown spermoderm and perisperm.

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[1] Ann. Jar. Bot. Buitenzorg. 1888, **7**, 151.

MICROSCOPIC STRUCTURE. Pericarp.—The five tissues are: (1) *epicarp* of polygonal cells; (2) *hypoderm* of rounded, small cells; (3) *outer mesocarp* of rounded or elongated, thin-walled pulp cells containing occasional small starch grains up to 7 μ, numerous white stone cells, with broad lumens, occurring singly or in small groups, elongated secretion cells with refractive contents, and occasional delicate fibro-vascular bundles; (4) *inner mesocarp* of elongated pulp cells radiating from the seeds; and (5) *endocarp* of polygonal or rounded, thick-walled, coarsely beaded cells.

The *starch grains*, occurring singly or in aggregates of two or three members, gradually disappear during ripening.

Spermoderm.—Four tissues, all brown, are present: (1) *outer epiderm* of polygonal cells; (2) *subepiderm* of small rounded cells; (3) a dense mass of elongated, thick-walled *sclerenchyma cells*, the outer portion with cells running for the most part longitudinally (excepting the somewhat parqueted outer layer), the inner portion with cells running transversely; and (4) *inner epiderm* of thin-walled, polygonal cells.

Perisperm.—This consists of a single layer of narrow elongated cells, with thickened outer wall and, as noted under Comparative Microscopic Structure of the group, rounded *secretion cells* protruding into the endosperm.

Endosperm.—This white tissue, forming the bulk of the seed, consists of rounded, thick-walled, porous cells containing small aleurone grains and oil. The walls stain red-blue with chlorzinc iodine.

CHIEF STRUCTURAL CHARACTERS.—Fruit sickle-shaped, nearly black. Seed brown, flattened, with thin spermoderm and ruminating endosperm.

Epicarp cells polygonal; mesocarp with starch cells, secretion cells, and stone cells; endocarp thick-walled and porous. Spermoderm with masses of elongated, brown sclerenchyma cells. Endosperm cells thick-walled, containing small aleurone grains and oil.

CHEMICAL COMPOSITION.—Langworthy and Holmes[1] were unable to find in the fruit any unwholesome constituent. An analysis of the edible portion (flesh) consisting of 74.8 per cent of the fruit gave as shown below:

Water	Protein	Fat	N-f. ext. + Fiber	Sugars, reducing	Sucrose	Ash
%	%	%	%	%	%	%
76.6	5.2	0.9	16.8	5.9	2.7	0.5

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[1] J. Home Econ. 1917, 9, 505.

SOURSOP

Annona muricata L.

Fr. Corossol. Sp. Guanabana. Ger. Saure Sobbe.

Safford states that the soursop is a native of tropical America. It is the most important annonaceous fruit grown in Cuba, Hawaii, and the Philippines, being especially prized for the preparation of sherbets, soda-water syrups, and jellies. The tree is also grown in the West Indies, Mexico, South America, India, Malaysia, and Africa. In Cuba the fruit is canned and preserved on a commercial scale. As a dessert fruit it is not equal to the sweetsop, cherimoya, or ilama.

MACROSCOPIC STRUCTURE.—The *flowers* are large, the exterior petals broad, thick, and fleshy, the interior petals smaller and thinner.

In form, size, and arrangement of the carpels, the *fruit* (Fig. 178), which is a syncarp, suggests a pineapple without the tuft of leaves. It is the largest of the annonas, reaching 2.5 kilos in weight. The skin is dark green, smooth, with a slightly recurved spine on each carpel. Longitudinal ridges, often inconspicuous, extend from spine to spine. The rind is several millimeters thick and does not, as in the sweetsop, readily separate from the edible flesh. The skin has a disagreeable odor and taste but the flesh is juicy, agreeably acid, variously described as resembling the pineapple or mango in flavor.

The dark brown, lustrous, flattened *seeds*, pointed at the base, reach 1.8 cm. in length. Longitudinal sections (Fig. 180, inset) cut at right angles to the flattened surface show clearly the dark leathery spermoderm with its thin transverse plates penetrating between the folds of the consolidated perisperm and endosperm. The spermoderm and its plates separate readily from the inner tissues. The minute embryo, situated in the pointed end, is seen with difficulty except after sprouting.

MICROSCOPIC STRUCTURE.—The **Rachis,** or core of the syncarp, consists of tissues similar to those of the mesocarp but the fibro-vascular bundles are more strongly developed.

Pericarp (Fig. 179).—The tissues are (1) *epicarp* (*epi*) of polygonal cells, often in longitudinal rows, interspersed with stomata and numerous two-jointed hairs (*t*), each on a small foot cell; (2) *hypoderm* of rounded characterless cells; (3) *outer mesocarp* (*mes*^{1}) of sclerenchyma containing minute starch grains, groups of nearly isodiametric stone cells (*st*) and occasional fibro-vascular bundles (*fv*); (4) *inner mesocarp* (*mes*^{2}) of rounded pulp cells containing, until mellow, small starch grains (*am*), secretion cells (*sec*), and delicate fibro-vascular bundles; and (5) *endo-*

carp (*end*) of narrow elongated porous (in surface view) cells adjoining the seed cavities.

The *starch grains* of the fruit pulp are isodiametric, rounded, or truncated and range up to 12 μ.

Spermoderm (Fig. 180, *S*).—Longitudinal sections show four brown tissues: (1) *outer epiderm* (*aep*) consisting of characterless, in surface view polygonal, cells with somewhat thickened outer walls; (2) *subepiderm* (*sub*) of small, in surface view rounded, cells with no evident contents forming a single or double layer; (3) dense tissue of thick-walled much-elongated *sclerenchyma cells*, in the outer portion (sc^1) longitudinally arranged, in the inner portion (sc^2), including the plates between the folds of the endosperm, transversely arranged; and (4) *inner epiderm* (*iep*) of cells similar to those of the outer epiderm, except that the walls are faintly porous.

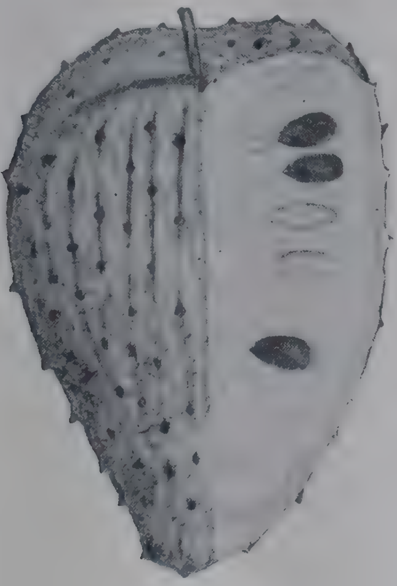

Fig. 178.

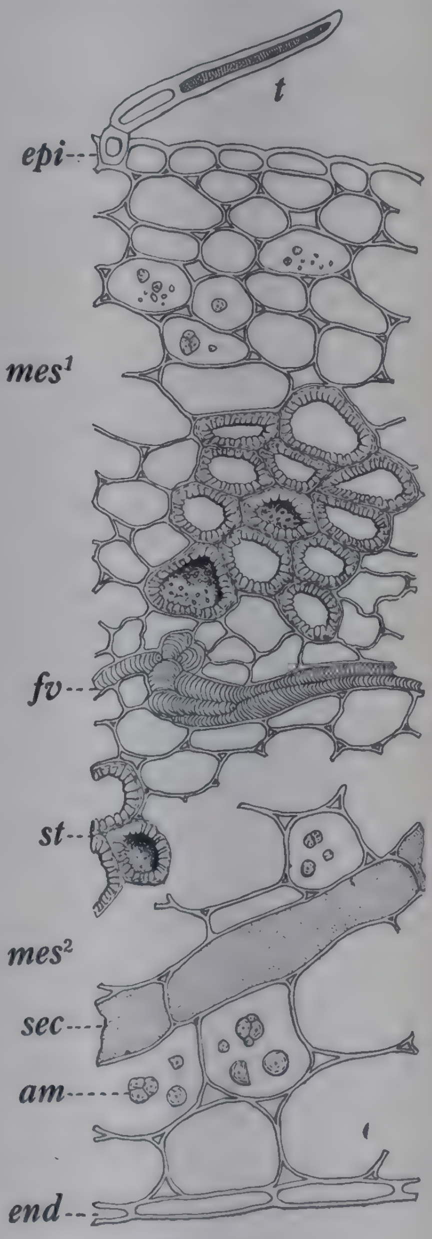

Fig. 179.

Fig. 178.—Soursop. Fruit. × ¼. (A.L.W.)

Fig. 179.—Soursop. Fruit in cross section. *epi* epicarp with *t* hair; mes^1 outer mesocarp with *fv* fibro-vascular bundle and *st* stone cells; mes^2 inner mesocarp of cells containing *am* starch grains and *sec* secretion cells; *end* endocarp. × 160. (K.B.W.)

Perisperm (Fig. 180, *N*).—Voigt[1] concludes that the single layer of small cells, mostly with very short, thin radial walls, appearing to form the outer layer of the endosperm, also large dark *secretion cells* (*ol*), containing oleoresin, occurring here and there beneath groups of the cells of the outer layer with longer radial walls, constitute the perisperm. He found that on treatment of longitudinal sections with chlorzinc iodine the walls of the perisperm cells stain yellow whereas those of the endosperm stain blue. Furthermore he found, and so shows in a cut of a related species, but we are unable to confirm, that the division wall between adjoining perisperm and endosperm cells is double, the outer part belonging to the former and the inner part to the latter.

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[1] Ann. Jar. Bot. Buitenzorg. 1888, **7**, 151.

Endosperm (Fig. 180, *E*).—The cells are characterized by their rounded form, thickened angles, and the pores in the thinner part of the walls. In addition to staining blue with chlorzinc iodine, they stain, as noted by Voigt, dirty red with iodine in potassium iodide. The visible contents are small aleurone grains (*al*), usually less than 5 μ but occasionally in the central cells reaching 8 μ.

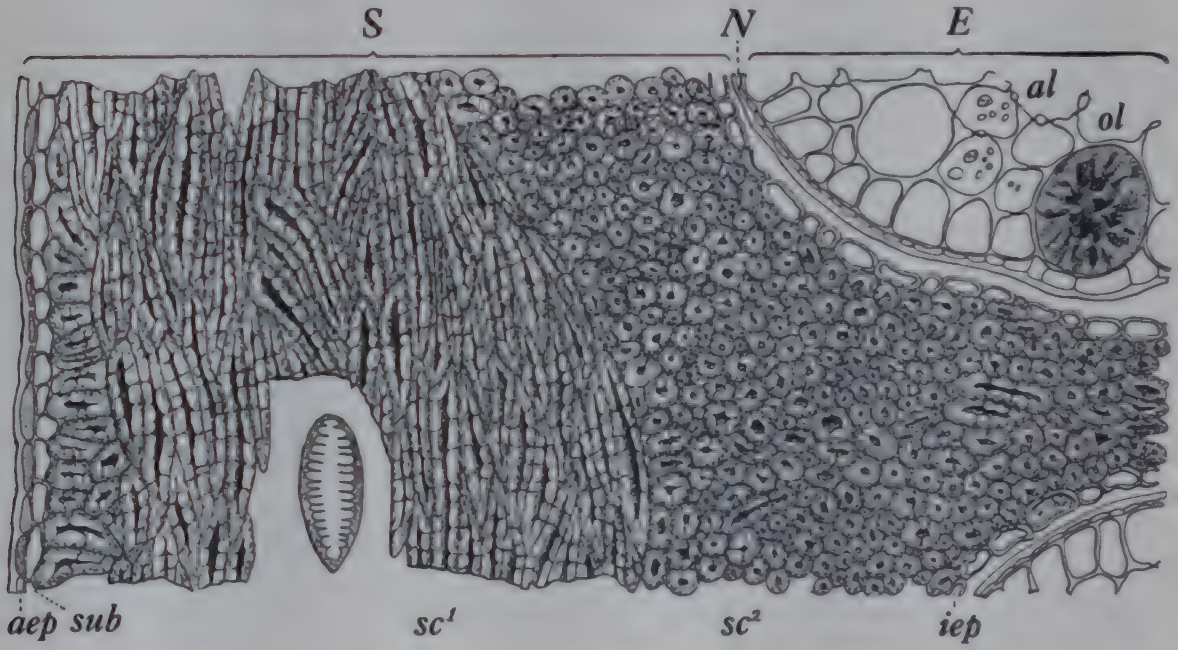

Fig. 180.—Soursop. Seed in longitudinal section. *S* spermoderm: *aep* outer epiderm; *sub* subepiderm; sc^1 longitudinally arranged sclerenchyma cells; sc^2 transversely arranged sclerenchyma cells; *iep* inner epiderm. *N* perisperm of empty, more or less compressed cells; *ol* secretion cell. *E* endosperm containing *al* aleurone grains. × 160. Inset, seed × 1. (K.B.W.)

Chief Structural Characters.—Fruit heart-shaped, large, dark green. Seed brown, flattened, with thin spermoderm and large ruminating endosperm.

Epicarp with hairs; mesocarp of starch parenchyma, stone cell groups, and secretion cells. Spermoderm of mass of elongated sclerenchyma cells. Perisperm of small cells and large oleoresin cavities. Endosperm of thick-walled cells containing small aleurone grains (8 μ).

CHEMICAL COMPOSITION.—For convenience in comparison, summaries of analyses of the different species of *Annona* are here given. The Cuban fruits were analyzed by Chace, Tolman, and Munson,[1] the Philippine by Pratt and Del Rosario,[2] and the Hawaiian by Thompson.[3] The following average weights of the different species are recorded: soursop, Cuban 325 and Philippine 650 grams; sweetsop, Cuban 212 and 246 and Philippine 240 grams; bullock's heart, Cuban 444 grams.

COMPOSITION OF FLESH OF ANNONACEOUS FRUITS

	Pulp in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as malic	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
Soursop:											
Cuban											
I	72	19.03	5.45	1.65	....	0.70	13.07	0.00	....	0.41	53
II	59	19.64	....	....	....	0.89	9.77	0.00	....	0.86	73
Philippine	69	22.6	3.4	0.38	....	1.04	10.80	7.72	....	0.85	93
Sweetsop:											
Cuban											
Min.†	27‡	25.44	4.78‡	1.89§	....	0.20	11.24‡	0.60‡	....	0.80	80
Max.†	30‡	29.00	6.19‡	2.13§	....	0.85	13.57‡	10.07‡	....	1.11	113
Aver.†	28‡	**27.82**	**5.49‡**	**2.05§**	....	**0.42**	**12.40‡**	**5.34‡**	....	**0.98**	**97**
Philippine	52	25.0	3.1	1.12	....	0.21	15.77	0.31	....	0.97	122
Hawaiian:											
I	53	21.33	4.07	2.04	0.55	0.29	16.51	0.00	1.63	0.84	..
II	56	24.82	5.48	1.53	0.55	0.17	15.27	2.88	1.22	0.67	..
Cherimoya:											
Hawaiian	84	33.81	9.86	1.84	0.15	0.09	15.34	3.07	4.29	0.67	..
Bullock's heart:											
Cuban	57	27.87	....	....	....	0.36	.....	0.00	....	1.04	110

* Cc. *N*/10 acid per 100 grams fruit. † 4 samples. ‡ 2 samples. § 3 samples.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[4] found 4.53 per cent, dry basis, in the fruit flesh.

Mineral Constituents.—Chace[5] found in the flesh of the soursop and bullock's heart 0.86 and 1.04 per cent of ash respectively. His analyses of the ash follow:

	K_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%
Soursop	48.93	0.44	2.17	9.15	4.54	1.48	3.40
Bullock's heart	49.73	2.21	0.66	6.57	4.49	....	7.40

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Philippine J. Sci. 1913, **8**, 59.

[3] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[4] Philippine Agr. 1932, **21**, 53.

[5] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

SONCOYA

Annona purpurea Moç. et Sessé

Other names for this fruit are *cabeza de negro* (negro head), *sencuya*, and *toreta*. The tree is seldom seen outside of Mexico, Central America, and Panama. Characteristic of the pulp are its highly aromatic odor and a flavor suggesting the mango.

MACROSCOPIC STRUCTURE.—The *flower* is much like that of the soursop. The *fruit* is large and nearly spherical with numerous pyramidal protuberances, up to 1.5 cm. or longer, grooved on one side and hooked at the end. Its surface is brown and felt-like. The pulp is of an orange color. The *seeds* are large, many reaching 3 cm. in length.

MICROSCOPIC STRUCTURE.—The structure differs little from that of the soursop. Although the spermoderm is somewhat thicker it agrees with the soursop in having no crystals in the *subepidermal layer*.

Chief Structural Characters.—Fruit large, brown. Seeds large (3 cm.).

Tissues similar to those of the soursop.

ILAMA

Annona diversifolia Safford

The ilama or ilamatzoptl, first described by Safford as being a distinct species, has practically the same range as the foregoing species. Since it is one of the most delicious table fruits of the genus, the trees are being planted by the plant introducers of the Department of Agriculture in the warmer sections of the United States.

MACROSCOPIC STRUCTURE.—The red-brown *flowers* have calyx lobes ending in a tuft of rusty hairs, three outer linear or oblong petals, and three inner minute petals. The *fruit* is much smaller and less elongated than the soursop, each carpel ending in a more or less distinct rounded protuberance, directed toward the apex, the whole being covered with a felt-like mass of hairs. The color varies from pale green with whitish flesh to pink with flesh similarly tinted. The *seeds* are somewhat longer (up to 2 cm.) than those of the soursop and cherimoya and only very slightly flattened.

MICROSCOPIC STRUCTURE.—As in the sweetsop and bullock's heart, the *subepidermal layer* of the spermoderm contains monoclinic crystals; otherwise the tissues resemble those of soursop.

Chief Structural Characters.—Fruit smaller and less elongated than that of soursop, green or pink. Seed large (2 cm.), only slightly flattened.

Crystals present in subepiderm of spermoderm; structure of pericarp and seed otherwise much like that of soursop.

CHERIMOYA

Annona Cherimola Mill.

Fr. Anone. Sp. Cherimoya. Ger. Cherimoyer.

Both De Candolle and Safford agree in considering this species indigenous to the higher regions of Ecuador and Peru. At an early date its culture was extended into Mexico and more recently into the West Indies and tropical and sub-tropical regions of South America and the Old World. Popenoe gives this fruit special prominence because of its wide climatic range, delicious flavor, and good shipping qualities but as yet the fruit is a rarity in northern markets.

MACROSCOPIC STRUCTURE.—The *flowers* are similar to those of the ilama but the color is greenish to yellowish. The *fruit* is about the size of that of the soursop, but is of a lighter green color and the surface varies in the different varieties from nearly smooth to strongly tuberculate. Safford[1] classifies the seedling cherimoyas under five heads: finger-printed (*impressa*), smooth (*lævis*), tuberculate (*tuberculata*), mamillate (*mamillata*), and umbonate (*umbonata*). The *seed* is about the same length as that of the sweetsop (1.5 cm.) but is somewhat thicker.

MICROSCOPIC STRUCTURE.—The structure resembles closely that of the soursop, crystals being absent in the *subepidermal layer* of the spermoderm.

Chief Structural Characters.—Fruit large, light green, smooth to tuberculate.

Minute structure similar to that of soursop.

CHEMICAL COMPOSITION.—See Soursop.

BULLOCK'S HEART

Annona reticulata L.

Fr. Cachiman. Sp. Anona. Port. Coração de boi.
Ger. Ochsenherzapfel.

From tropical America, where it is indigenous, the bullock's heart has been carried to tropical regions of the Old World, although the flavor of the fruit is much inferior to that of the other common species.

---

[1] Bailey: Stand. Cycl. Hort., New York, 1922.

MACROSCOPIC STRUCTURE.—The outer petals of the *flower* are oblong or linear, fleshy, greenish or yellowish with a purple blotch on the inner side at the base; the inner petals are minute. The *fruit* is heart-shaped, up to more than 12 cm. in length, of a red-brown color, with a smooth surface more or less distinctly divided into several-sided, slightly elevated areoles. Safford states that it is often confused with the smooth-fruited forms of cherimoya but is inferior in flavor. The *seed* is quite similar to that of the sweetsop, being 1.5 cm. in length.

MICROSCOPIC STRUCTURE.—As in the case of the soursop, the fruit when fully formed, but not mellow, has pulp containing a considerable amount of *starch*, the grains ranging up to 15 μ in diameter. The *subepidermal layer* of the spermoderm contains monoclinic crystals.

CHIEF STRUCTURAL CHARACTERS.—Fruit heart-shaped, red-brown, smooth. Seed similar to that of sweetsop.

Starch present in pulp tissues. Subepiderm of spermoderm with crystals.

CHEMICAL COMPOSITION.—See Soursop.

SWEETSOP

Annona squamosa L.

Fr. Pomme-cannelle. Sp. Anona blanca. Port. Pinha.
Ger. Zimtapfel.

Other common English names are the custard-apple and sugar apple.

As is true of the bullock's heart, this species is native in tropical America but is widely cultivated throughout the tropics. Popenoe states that, with the exception of the ilama, it is the best of the tropical annonas and that it is more extensively cultivated than any other species. It is so commonly grown in India as to have led to the belief that it was native.

Although valuable as a dessert fruit, it is not suited for cooking. Its shipping qualities are poor. The fruit pulp is custard-like.

MACROSCOPIC STRUCTURE.—The *flowers* resemble those of bullock's heart. The *fruit* is usually more nearly spherical and smaller than in the other common species, seldom exceeding 8 cm., and the carpels are more loosely attached to one another. The exposed portion of each carpel is rounded or rounded-conical with a groove on the inner side, of a greenish yellow color with a bloom. The flattened *seed* is the same length (1.5 cm.) as that of the soursop but not quite so broad.

MICROSCOPIC STRUCTURE.—The fruit flesh is free from starch when fully ripe. In cell structure it shows no marked difference from the soursop. Monoclinic crystals are present in the *subepidermal layer* of the spermoderm.

CHIEF STRUCTURAL CHARACTERS.—Fruit spherical, small (8 cm.), greenish yellow; carpels loosely attached. Seed (1.5 cm.) flattened.

Fruit tissues without starch when mellow. Subepiderm of spermoderm with crystals.

CHEMICAL COMPOSITION.—See Soursop.

Oil.—Kafuku, Hata, and Fugikawa [1] give the following values for the oil from seeds containing water 11.0, oil 14.75, and ash 1.49 per cent: specific gravity at 30°/4° C. 0.9127, refractive index at 30° C. 1.4660, saponification number 188.8, iodine number 80.9, acid number 5.3, and unsaponifiable matter 0.35 per cent.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan [2] reports 2.85 per cent, dry basis, in the fruit flesh.

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[1] J. Chem. Soc. Japan 1934, **55**, 375.

[2] Philippine Agr. 1932, **21**, 53.

FRUITS OF THE LAUREL FAMILY

(*Lauraceæ*)

Only one table fruit, the avocado, belongs in this family. Species of other genera yield spices or essential oils but the valuable part is flower bud (cassia buds), bark (cassia, cinnamon), leaf (bay leaf), or root (sassafras).

The chief characters of the avocado are its oily mesocarp and large starchy embryo. Further details appear in the following description.

AVOCADO

Persea americana Mill. = *P. gratissima* Gaertn.

Fr. Avocat. Sp. Ahuacate. Port. Abacate. Ger. Avogado.

Some botanists consider the common cultivated market types of avocado as varieties of the same species, others as belonging to two species: *P. americana* Mill. with thick, leathery or brittle rind, including the Guatamalan and West Indian varieties, and *P. drymifolia* Cham. et Schlecht. with anise-scented leaves and leathery rind, including the Mexican varieties. Popenoe adopts the first view in his article in Bailey's Standard Cyclopedia, the second in his Manual of Tropical and Subtropical Fruits. In the latter he also mentions two other species the *coyo* or *chinini* (*P. Schiedeana* Nees) of southern Mexico and Guatemala and *yás* (*P. Pittieri* Mez) of Costa Rica. Growers in California and Florida insist on the abandonment of the name " alligator pear."

The avocado, the olive, and the Chinese olive (see Vol. I) are the only cultivated succulent fruits in which fatty oil is the characteristic and predominating dry constituent, thus sharply differentiating the group from saccharine and starchy fruits. The avocado is also richer in protein than other fruits but lacks noticeable acidity.

MACROSCOPIC STRUCTURE.—Numerous small, greenish, apetalous *flowers* grouped in terminal racemes form the inflorescence. The perianth has six lobes in two series. There are nine stamens in three series, the inner with nectar glands at the base, and three staminodes. The ovary contains a single ovule.

The *fruit* (Fig. 181) is pear-shaped, ovoid, or nearly ellipsoidal, up to 15 cm. or more long. The color is glossy green or various shades of yellow, dark red, brown, purple, or nearly black. An excentric depressed spot marks the true apex. In cross section the cut surface of the fruit flesh (pericarp) shades from the green in the thin rind to the cream color or yellow of the uniform oily mesocarp. The thin but shell-like endocarp is often grown to the spermoderm of the large anatropous *seed* which completely fills the fruit cavity.

On removing the seed the outer spermoderm often remains with the endocarp, the inner spermoderm with the embryo. This phenomenon gave rise to the statement that in some varieties the spermoderm is in two layers. The separation, however, as a study of the histology shows, is mechanically through the middle layers of the spermoderm where ramify the raphe and its numerous branches. A similar splitting of the spermoderm takes place when the meat of the cocoanut separates from the shell. The embryo is remarkably large, often weighing more than 100 grams. It consists of fleshy cotyledons and a small radicle directed toward the stem end.

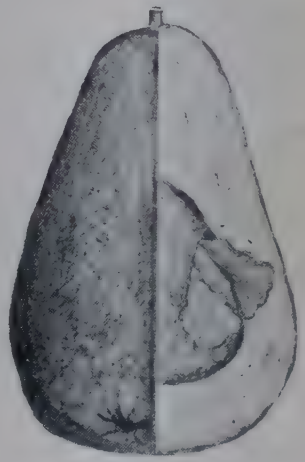

FIG. 181.—Avocado. Fruit in longitudinal section showing seed with endocarp and spermoderm partly torn away exposing the wrinkled cotyledons. ×¼. (A.L.W.)

MICROSCOPIC STRUCTURE.—Owing evidently to the degree of maturity of the fruit when picked, the tissues, particularly those of the endocarp and spermoderm, show perplexing differences in structural details.

Pericarp (Figs. 182 and 183).—Cross and surface sections of well-matured fruit bring out five layers or zones: (1) *epicarp* (*epi*) of polygonal cells, often with obvious division by thin walls into daughter cells, containing chlorophyl grains; (2) *hypoderm* of ten to twenty rows of medium-sized chlorophyl cells, and small oleoresin cavities (*r*); (3) *stone cells* (*st*), often of grotesque form, in groups; (4) *mesocarp* of loose parenchyma cells, containing much fatty oil (*ol*), oleoresin cavities, and fibro-vascular bundles; and (5) *endocarp* (*end*) of curious sclerenchyma cells.

The *oleoresin cavities* are cell-like in character and the contents appear to be solid. The bulk of the *fatty oil* is in the mesocarp. Both sinuous-walled isodiametric and tangentially elongated cells occur in the *endocarp*, the former being in groups from which the latter radiate. The walls are in some parts delicately reticulated, in others porous. This layer is cemented here and there to the spermoderm by a brown substance which extends also into the cells of both layers, obscuring the structure.

Spermoderm (Fig. 183).—Of the three layers, namely (1) *outer epiderm*, (2) *spongy parenchyma*, and (3) *inner epiderm*, only spongy parenchyma, through which run the raphe and its numerous branches, is well marked and characteristic.

Part of the *spongy parenchyma* cells are thin-walled but many of them are sclerenchymatized and variously pitted or reticulated. In what appear to be immature seeds, the cells (sc^2) are small, rounded, and show delicate spiral reticulations; in fully ripened seeds, the cells (sc^1) are larger and irregular in shape with relatively small pores. Cross sections of ripe seeds show conspicuously the raphe vessels in fan-shaped arrangement.

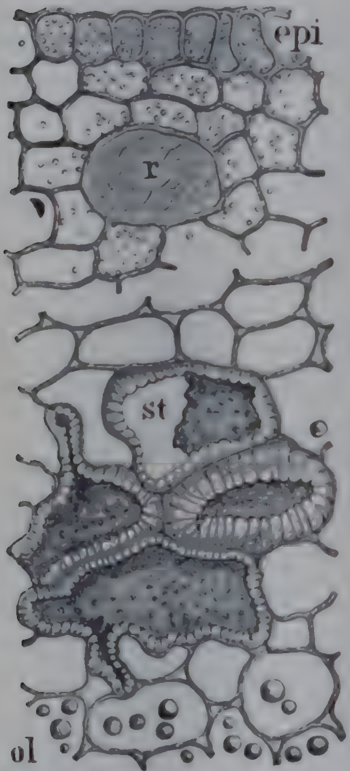

FIG. 182.

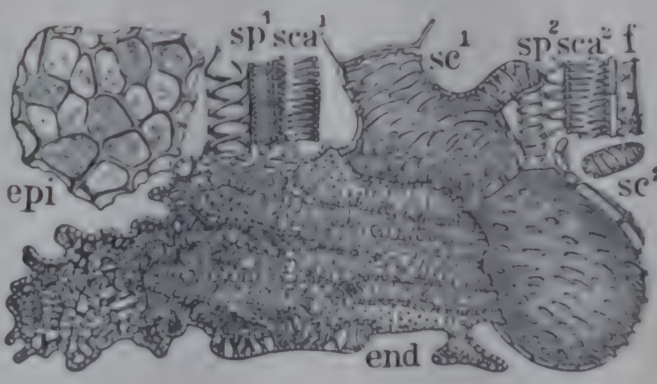

FIG. 183.

FIG. 182.—Avocado. Outer layers of pericarp in cross section. *epi* epicarp with chlorophyl grains; hypoderm with *r* oleoresin cavity; *st* stone cells; *ol* oil parenchyma of mesocarp. × 160. (A.L.W.)

FIG. 183.—Avocado. Elements of fruit and seed in surface view. *epi* epicarp with chlorophyl grains; sp^1 spiral and sca^1 scalariform vessels of a mesocarp fibro-vascular bundle; *end* endocarp; sc^1, sc^2 sclerenchyma cells of spermoderm; sp^2 spiral and sca^2 scalariform vessels and *f* bast fiber of raphe. × 160. (A.L.W.)

Embryo.—Because of oxidases, cut surfaces of the cotyledons become a deep orange color on exposure to the air. The cells contain a rich store of starch which would make the seeds of high food value were it not for the bitter taste. Attempts to prepare starch from the seeds of market fruits by grating and elutriation were unsuccessful, owing perhaps to the immaturity, but the deep orange color imparted to the water by the oxidases suggested a possible field for research.

The *starch grains* (Fig. 184) are ovoid, truncated, triangular, or of various curious irregular forms, up to 33 μ long, with excentric hilum and distinct rings. Aggregates, most commonly of two grains, occur frequently.

Chief Structural Characters.—Fruit pear-shaped or ovoid; rind either leathery or brittle or else skin-like; mesocarp yellow or cream color, soft, oily; endocarp thin. Seed large; outer spermoderm often adhering to endocarp; embryo large, becoming orange on cut surface.

Hypoderm with chlorophyl cells and oleoresin cavities; stone cell zone beneath hypoderm; mesocarp of oil cells and oleoresin cavities; endocarp of characteristic sclerenchyma cells. Middle layer of spermoderm spongy and partly sclerenchymatized: Cotyledons containing characteristic large starch grains with excentric hilum.

CHEMICAL COMPOSITION.—The fatty nature of the fruit is brought out by quantitative analyses, thus corroborating the findings of microscopic examination.

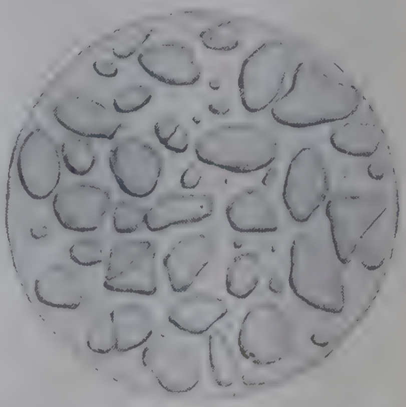

Fig. 184.—Avocado. Starch from seed. × 160. (A.L.W.)

The results of three French analysts, Garcia,[1] on Peruvian fruit, Patrault,[2] on a sample of unknown origin, and De Sornay,[3] on green and ripe fruits grown at low and high altitudes in Mauritius, show that less than half of the solids were fat. On the other hand the results of Jaffa[4] and Jaffa and Goss,[5] who analyzed respectively 28 and 83 samples of California fruit, and Stoneback and Calvert,[6] who analyzed the fruit of a Guatemalan variety, Collins, show that fat averaged from two-thirds to three-quarters of the solids. The results of the authors named appear on the next page.

A maximum of 7.6 per cent of fat was found by Wardlaw[7] in avocados grown in Trinidad.

Composition of Avocado Seeds.—Weatherby and Sorber[8] analyzed the seeds of varieties of Mexican and Fuerte avocados with results on the original basis given in the second table on the next page.

Changes in Composition During Growth and Storage.—Church and Chace[9] noted a rapid increase in fat and a decrease in sugars during

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[1] Bul. ass. chim. sucr. dist. 1907, **24**, 516.

[2] Ibid. 1908, **25**, 777.

[3] Rev. agr. Maurice 1923, **1**, 72.

[4] California Agr. Exp. Sta. 1915, Bul. **254**, 395.

[5] Ibid. 1923, Bul. **365**, 630.

[6] Am. J. Pharm. 1923, **95**, 598.

[7] Trop. Agr. (Trinidad) 1934, **11**, 27.

[8] Ind. Eng. Chem. 1931, **23**, 1421.

[9] U. S. Dept. Agr., Bur. Plant Ind. 1922, Bul. **1073**.

COMPOSITION OF AVOCADO FLESH

	Weight of fruit	Flesh	Water	Protein	Fat	N-f. ext.	Sugars	Fiber	Ash
	g.	%	%	%	%	%	%	%	%
Garcia			38.00	3.79	34.10	28.10*	....	....	3.50‡
Patrault			82.1	1.2	8.7	4.6*	2.9	....	0.5
De Sornay:									
Green, low altitude			78.03	1.35	9.49	8.96	1.90	1.17	1.00
Green, high altitude			86.20	1.46	5.81	4.66	1.68	1.17	0.70
Ripe, low altitude			82.50	0.87	8.17	6.32	1.22	1.19	0.95
Ripe, high altitude			86.50	1.23	6.96	3.21	1.52	1.15	0.95
Jaffa:									
Min.	92	43	61.08	1.30	9.8	3.69	....	....	0.60
Max.	638	83	79.66	3.70	29.1	16.17	....	....	1.93
Aver.	**197**	**66**	**69.16**	**2.08**	**20.10**	**7.39***	....	....	**1.26**
J. and G.:									
Min.	79	53	58.71	1.14	9.78	2.59	....	....	0.54
Max.	926	86	82.31	4.39	31.60	10.00	....	....	1.94
Aver.	**347**	**68**	**70.56**	**2.10**	**20.06**	**5.95**	....	....	**1.32**
S. and C.			66.00	1.21	25.26	6.44†	....	....	1.09

* Includes fiber. † Carbohydrates. ‡ P_2O_5 0.82%.

COMPOSITION OF AVOCADO SEEDS (WEATHERBY AND SORBER)

	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Starch	Pentosans	Arabinose	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
Mexican:											
I	58.51	2.38	0.70	33.41	....	....	.....	....	....	3.76	1.24
II	52.14	....	0.91	.....	2.58	0.92	.....	1.73	2.15	4.14	
III	51.86	....	1.00	.....	....	....	27.54	....	....	....	
Fuerte:											
I	50.56	2.45	0.99	.....	1.60	0.61	29.60	1.64	2.04	....	1.34
II	49.91	....	1.10	.....	....	....	.....	....	....	3.65	

development. During storage immature fruit appeared to undergo changes similar to those taking place during development, while mature fruit changed but little. Numerous analyses, reported by Stahl,[1] indicate that the oil increases rapidly during the early stages of development and more slowly during the later stages (stored fruit maximum 25.23 per cent, fresh basis, and 75.73 per cent, dry basis), whereas the reverse is true of moisture. Sugars, protein, and ash show slight or variable change.

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[1] Florida Agr. Exp. Sta. 1933, Bul. 259.

Proteins.—Three proteins have been isolated from the pulp by Jones and Gersdorff:[1] I, similar to a globulin, separated from a 10 per cent salt solution by acetic acid or by adding ammonium sulphate to 67 per cent saturation, II obtained from the residue insoluble in salt solution by extraction with tenth normal sodium hydroxide in 60 per cent alcohol and precipitation with acid, and III obtained by diluting the filtrate from II.

The average *ultimate composition* of the three proteins, on the water- and ash-free basis, was as follows:

	I	II	III
	%	%	%
Carbon	52.92	56.54	55.43
Hydrogen	8.24	7.10	7.42
Nitrogen	15.31	13.43	16.23
Sulphur	2.89	2.04	1.89
Oxygen	20.64	20.89	19.03

Amino acids were determined with the results given in the following table:

	I	II	III
	%	%	%
Cystine	2.03	1.84	1.80
Tyrosine	7.01	4.92	2.81
Tryptophane	2.12	0.38	1.07
Arginine	7.94	4.46	12.94
Lysine	7.06	6.71	2.95
Histidine	0.59	2.04	0.99

Determination of the *nitrogen distribution* by Van Slyke's method gave for I, II, and III respectively: humin N adsorbed by lime 3.15, 7.49, and 5.06; humin N in amyl-alcohol-ether extract 0.16, 0.11, and 0.44; cystine N 1.55, 1.60, and 1.28; arginine N 16.74, 10.67, and 25.51; lysine N 8.86, 9.57, and 4.64; histidine N 1.04, 4.10, and 1.64; amino

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[1] J. Biol. Chem. 1929, **81**, 533.

N of filtrate 60.47, 55.38, and 48.12; non-amino N of filtrate 2.88, 3.04, and 6.90; and amide N 6.03, 8.91, and 5.35 per cent.

Oil.—From the dried flesh, Albro[1] obtained the oil by extraction with low-boiling-point gasoline, filtration through animal charcoal, removal of the gasoline with carbon dioxide, and decantation at 5° C. Values of the oil appear in the table below:

	Ref. index 25° C.	Maumené No.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Hehner No.	Acetyl No.	Acid No.
Min......	1.4664	65	177	85	3.8	0	92.5	11.3	8
Max......	1.4664	65	178	88	4.0	0	92.5	11.3	12

The molecular weight of the fatty acid was 282.2, the refractive index at 40° C. 1.454, the calculated oleic acid 80.85 per cent. Oil extracted with petroleum ether from the fresh pulp showed acid values twice that of the oil from the dried flesh, but the other values were similar.

Carbohydrates.—Bertrand,[2] through the agency of oxidizing bacteria, prepared *perseulose* from a constituent of the avocado which he believed to be perseite and claimed that this was the first reducing heptose produced by a living cell.

La Forge[3] isolated *d-mannoketoheptose* from the same fruit and showed that its configuration is:

$$HOCH_2 \cdot HCOH \cdot HCOH \cdot HOCH \cdot HOCH \cdot CO \cdot CH_2OH$$

It is stated that this is the first heptose found in nature and the fourth natural ketose isolated. La Forge further showed that the avocado contains an alcohol *d-perseitol* which is the constituent from which Bertrand obtained perseulose and that the probable configuration of perseulose is:

$$HOCH_2 \cdot CO \cdot HCOH \cdot HOCH \cdot HOCH \cdot HCOH \cdot CH_2OH$$

d-Perseite or *α-d-mannoheptite* ($C_7H_{16}O_7$), a heptahydroxy alcohol, was first found by Avequin[4] in the seed of the avocado. Fischer and

[1] Ann. Rep. Cal. Avocado Ass. 1917, p. 92.

[2] Compt. rend. 1908, **147**, 20; 1909, **149**, 225.

[3] J. Biol. Chem. 1917, **28**, 511.

[4] Ann. Chem. Med. Ph. Toxic. 1831, **7**, 467.

Passmore[1] prepared it by reduction of *d*-mannoheptose and established ts constitution to be as follows:

$$CH_2OH\cdot HOCH\cdot HOCH\cdot HCOH\cdot HCOH\cdot CHOH\cdot CH_2OH$$

Weatherby and Sorber[2] show a photomicrograph of crystals of *d*-perseite obtained by boiling ground avocado seeds with 80 per cent alcohol and allowing the extract to stand for one or more days.

Tannin.—The tannin isolated by Bilger, Young, and Robbins[3] constitutes 0.07 per cent of the dry matter. A sterol was isolated from the oil.

Phosphorus-Organic Compounds. *Phytin.*—In *P. americana* and *P. americana* var. *Lyon*, Bagaoisan[4] found respectively 2.45 and 1.25 per cent, dry basis.

Mineral Constituents.—The following ash analysis by Jaffa and Goss[5] appears to be of the whole fruit and is consequently of chief interest in the study of soil depletion:

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
%	%	%	%	%	%	%	%	%	%	%
26.23	18.55	4.72	5.30	1.51	2.58	trace	17.40	11.24	0.50	14.36

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[1] Ber. 1890, **23**, 2226.

[2] Loc. cit.

[3] Hawaii Agr. Exp. Sta. Rep. 1931, p. 14.

[4] Philippine Agr. 1932, **21**, 53.

[5] Loc. cit.

FRUITS OF THE SAXIFRAGE FAMILY

(*Saxifragaceæ*)

The bush berries of this family belong in the two sections of the genus *Ribes,* (1) *Ribes* proper or currants and (2) *Grossularia* or gooseberries.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *flowers* are five-merous with calyx tubular below, lobed above, and petals alternating with the calyx lobes on the tube. The inferior ovary is one-celled with two parietal placentæ and two styles, often more or less united.

After blooming, the *perianth* persists, crowning the fruit. It is long in the gooseberries and black currant (6 or 7 mm.), shorter in the red currant (about 2 mm.). The *fruit* is smooth, excepting the European gooseberry which bears prickles. Ten meridian-like bundles are seen through the transparent outer fruit tissues.

As in the pomegranate, the *seeds* have a succulent outer spermoderm which in this genus is also gelatinous. The inner spermoderm is thin, enclosing the bulky endosperm. A minute embryo is embedded in the endosperm at the base.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—The *epicarp* is of more or less beaded polygonal cells. The prickles occurring on the European gooseberry are either blunt-pointed or capitate. Disk-shaped glands occur on the black currant. The *hypoderm* is made up of polygonal collenchyma cells and the mesocarp of large polygonal cells—in the gooseberry mostly separated by chains of small cells—many containing oxalate rosettes. Both red and black currants have a striking endocarp of sclerenchymatous and parqueted cells, while gooseberries have an inconspicuous thin-walled endocarp.

Spermoderm.—The cells of the outer epiderm are enormously elongated in radial directions. Beneath is a *parenchymatous tissue,* then a single layer of *crystal cells,* with thickened walls, containing monoclinic crystals, and finally an *inner epiderm* of narrow elongated cells.

Perisperm.—Structureless.

Endosperm.—The walls are moderately thick and in the inner part knotty-thickened. Aleurone grains up to 10 μ are the visible contents.

Embryo.—Characterless.

COMPARATIVE CHEMICAL COMPOSITION.—Berries of this group are characterized by high acidity (citric and malic) and high pectin content.

RED CURRANT

Ribes vulgare Lam. = *Ribes rubrum* not L.

Fr. Groseille. Sp. Grosellero rojo. It. Ribes rosso.
Ger. Johannisbeere.

Rehder[1] states that *R. vulgare*, a native of western Europe, is the parent of most of the cultivated currants, although some are crosses with *R. rubrum* L., a species largely restricted to its habitat in central and northern Europe and northern Asia. The two species, however, are commonly grouped together as *R. rubrum*, De Candolle giving the habitat as northern and temperate Europe, Siberia, and from Canada and Vermont to the mouth of the Mackenzie River, the last-named range, credited to Torrey and Gray, doubtless referring to *R. rubrum* L. var. *subglandulosum* Maxim.

Whatever the origin, fruits of the principal horticultural varieties of both red and white currants grown in the United States agree in morphology and microscopical characters.

The currant is much used for jams, jellies, preserves, and to a limited extent as a dessert berry.

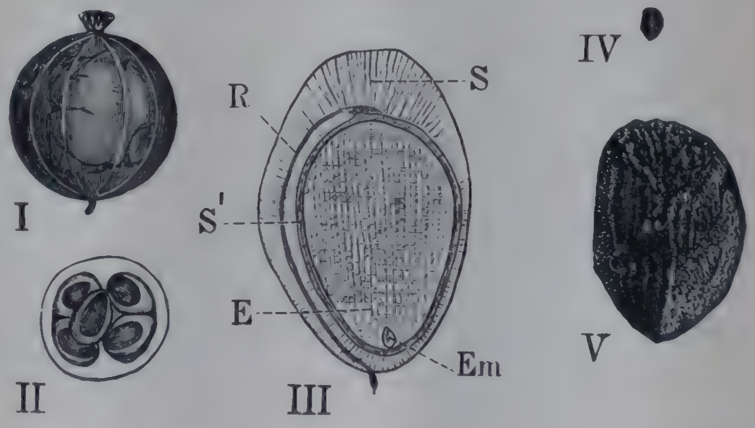

Fig. 185.—Red Currant. I fruit, × 1. II fruit and seeds in cross section, × 1. III seed in longitudinal section: *S* outer, *S'* inner spermoderm; *R* raphe; *E* endosperm; *Em* embryo. × 8. IV seed deprived of gelatinous coat, × 1. V same as IV, × 8. (A.L.W.)

MACROSCOPIC STRUCTURE.—Passing over the characters of the ring and anthers, distinguishing the two species, the *flowers* have a five-lobed bell-shaped calyx (shorter than in the gooseberry), five petals borne on the calyx throat and smaller than the calyx lobes, five stamens, and a one-celled inferior ovary with two styles and two parietal placentæ.

On ripening, the calyx shrivels and remains attached to the *fruit* (Fig. 185, I), and the ten main bundles running to the floral envelopes form meridian-like lines seen through the transparent tissues. The

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[1] Bailey Stand. Cycl. Hort., New York, 1922.

seeds (II, III, IV, V), up to eight in number, are anatropous and closely crowded. The raphe (R) is visible through the outer transparent spermoderm (S). A thin inner spermoderm (S') encloses the endosperm (E) in which, at the base, is embedded the minute embryo (Em).

MICROSCOPIC STRUCTURE.—Blyth[1] and Villiers and Collin[2] briefly describe certain tissues of the pericarp; Lampe[3] and Winton[4] studied the pericarp and the latter also the seed.

Pericarp (Figs. 186 and 187).—Cross sections show four layers, the characters of which are seen in surface view: (1) *epicarp* (*epi*) of more or less beaded cells and stomata (*sto*); (2) *hypoderm* (*hy*) of polygonal cells larger than those of the epicarp; (3) *mesocarp* of large thin-walled cells, those in the inner part often with crystal rosettes and fibrovascular bundles (B); and (4) *endocarp* (Fig. 187) of parqueted sclerenchyma cells characteristic of the currant group.

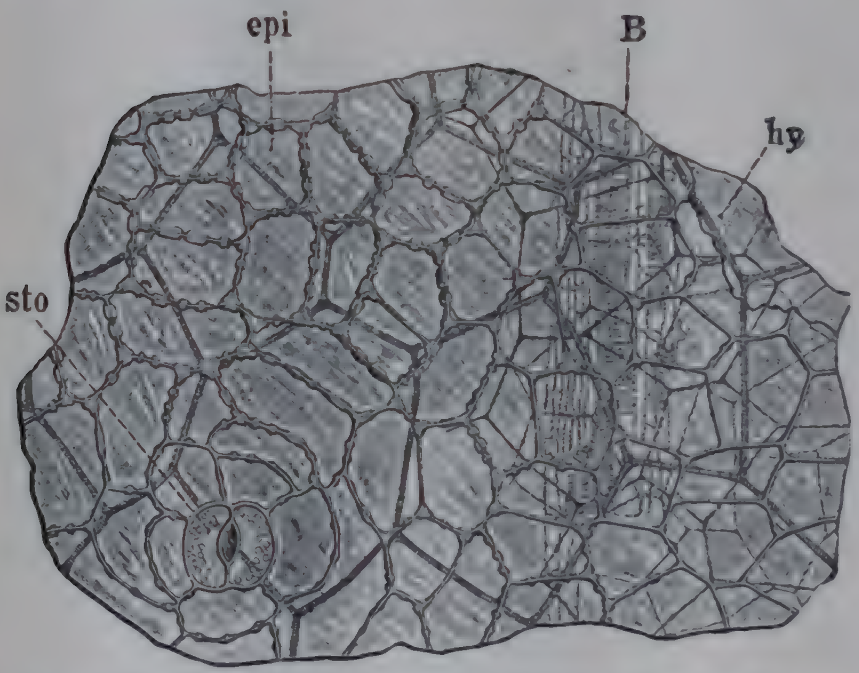

FIG. 186.—Red Currant. Outer pericarp in surface view. *epi* epicarp with *sto* stoma; *hy* hypoderm; *B* fibrovascular bundle seen through outer tissues. × 160. (A.L.W.)

Spermoderm (Fig. 188, S; Fig. 189).—Four strikingly different layers are present: (1) *outer epiderm* (*aep*) of mucilaginous cells, often more than 600 μ high at apex; (2) *parenchyma* (p) several cells thick; (3) brown *crystal cells* (k, K) with thickened inner and radial walls each with a single monoclinic oxalate crystal; and (4) *inner epiderm* (*iep*) of narrow, longitudinally elongated cells.

Perisperm (Fig. 188, N).—In cross sections, a narrow band of compressed cells, about 10 μ thick, is seen between the spermoderm and the endosperm. This is perisperm.

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[1] Foods, etc., London, 1896, p. 162.

[2] Traité Altér. Fals. Subs. Aliment., Paris, 1900, p. 828.

[3] Z. Naturwiss. 1886, **59**, 295.

[4] Z. Unters. Nahr.-Genussm. 1902, **5**, 785; Connecticut Agr. Exp. Sta. Rep. 1902 p. 288.

Endosperm.—Cells with rather thick walls (about 2 to 3 μ), containing aleurone grains up to 10 μ, constitute the endosperm. In the outer part (Figs. 188 and 189, *E*), the cells are somewhat radially elongated with uniformly thickened walls, but in the center (Fig. 190)

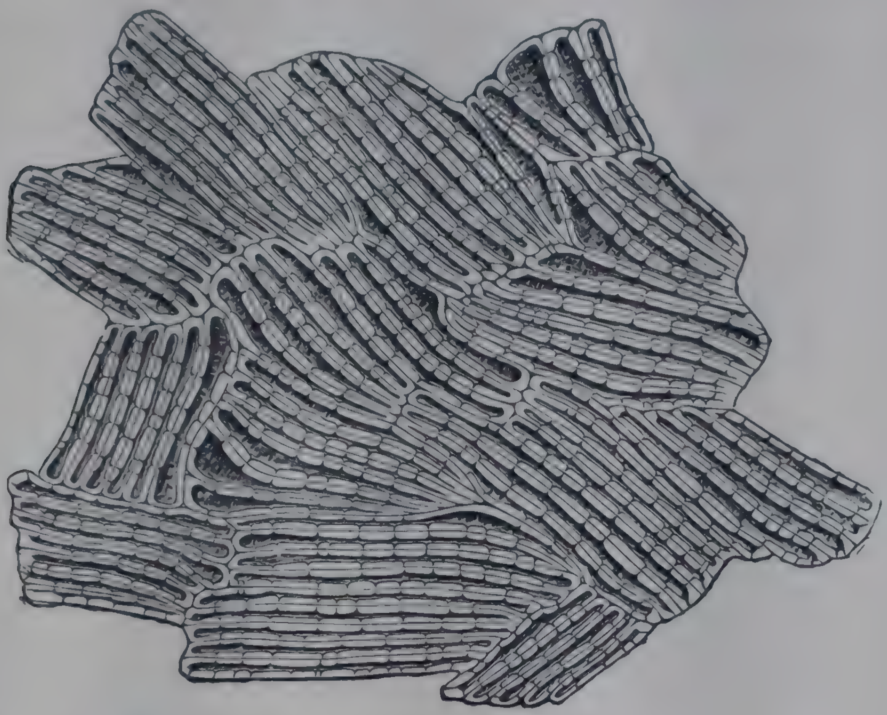

Fig. 187.—Red Currant. Endocarp in surface view. × 160. (A.L.W.)

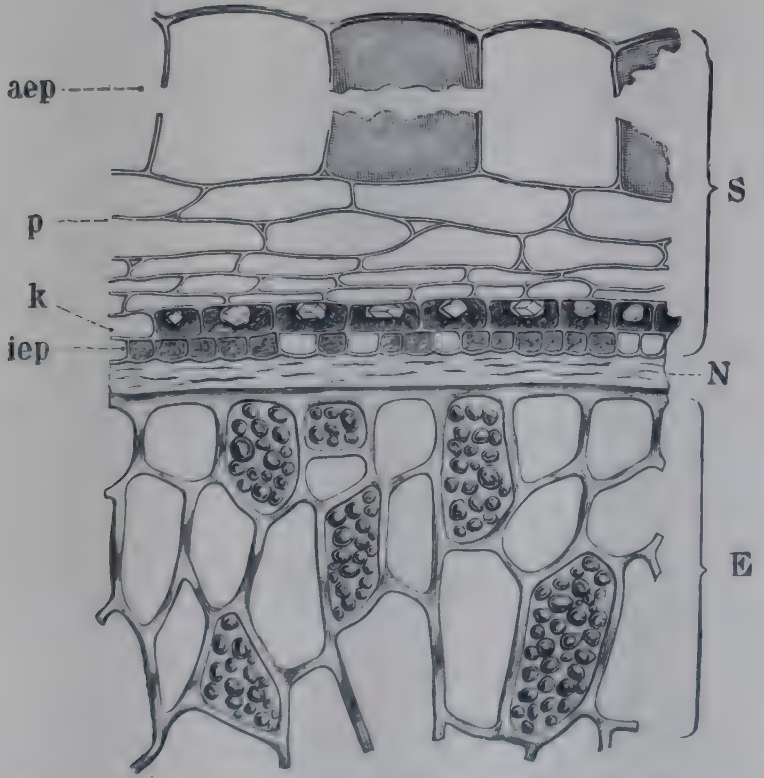

Fig. 188.—Red Currant. Seed in cross section. *S* spermoderm: *aep* outer epiderm, *p* parenchyma, *k* crystal layer, and *iep* inner epiderm. *N* perisperm. *E* endosperm. × 300. (A.L.W.)

they are isodiametric with remarkable knotty thickenings at the angles and often in the middle of the walls.

Chief Structural Characters.—Berry globular, crowned with short calyx; main bundles ten; seeds several. Seed with gelatinous outer spermoderm, bulky endosperm, and minute embryo.

Epicarp of polygonal cells with beaded medium-thick walls, non-beaded thin walls, and stomata; inner mesocarp with crystal rosettes; endocarp of parqueted sclerenchyma cells. Outer epiderm of spermoderm of mucilaginous cells up to 600 μ high; third layer of crystal cells with thickened membrane. Endosperm of thick-walled aleurone cells, knotty thickened in center of the seed.

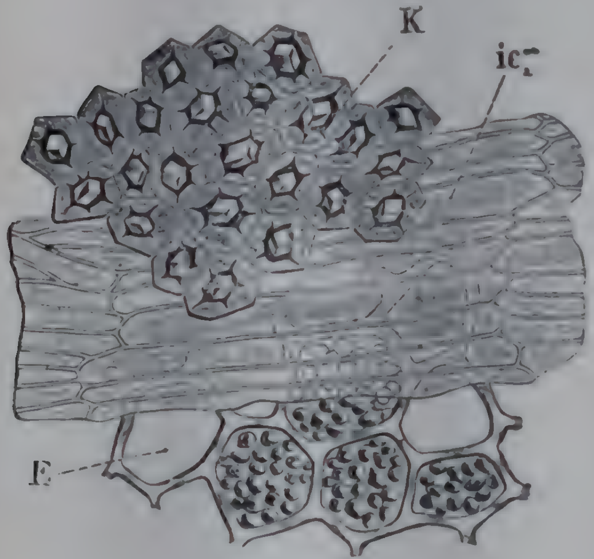

Fig. 189.

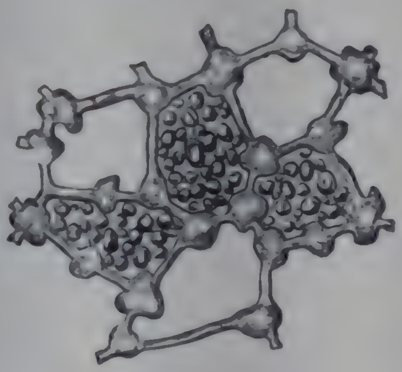

Fig. 190.

Fig. 189.—Red Currant. Elements of seed in surface view. *K* crystal layer and *iep* inner epiderm of spermoderm; *E* endosperm. × 300. (A.L.W.)

Fig. 190.—Red Currant. Central portion of endosperm in cross section. × 300. (A.L.W.)

CHEMICAL COMPOSITION.—Kulisch,[1] Ystgaard,[2] Munson, Tolman, and Howard,[3] and Olig[4] appear to have analyzed the whole fruit, but doubtless with the stem excluded; Girard[5] analyzed the pulp. Hotter[6] analyzed the pulp of 4 samples of red and 2 samples of white Austrian currants. See tables next page.

Composition of Currant Juice.—The three authors who have made outstanding contributions to the composition of the juice, quoted

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[1] Z. angew. Chem. 1894, p. 148.

[2] Tids. Norske Landbr. 1902, **9**, 125.

[3] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **66** rev.

[4] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

[5] Min. Agr. France Bul. 1898, **17**, 1523.

[6] Z. landw. Versuchsw. 1906, **9**, 747.

COMPOSITION OF CURRANT

	Samples	Solids, total	Solids, insol.	Protein	Acids as citric	Invert sugar	Sucrose	Pectin	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	%	cc.
Whole fruit										
Kulisch:										
Red.......	1	14.70	....	1.44	2.24	5.75	....	....	0.59	..
White......	1	17.60	....	1.56	1.77	6.06	....	....	0.61	..
Ystgaard:	4									
Min........		12.60	....	....	2.30	3.70		....	....	..
Max.......		16.00	....	....	2.70	4.30		....	....	..
Aver.......		**14.75**†	....	....	**2.51**	**3.94**		....	....	..
Munson et al.:	1	12.97	6.90	1.37	2.21	3.44	0.00	0.80‡	0.60	63
Olig:	3									
Min........		14.48	4.79	....	1.75	5.18	0.46§	....	0.49	31
Max.......		16.72	7.33	....	2.18	6.58	0.46§	....	0.66	47
Aver.......		**15.29**	**6.16**	....	**1.90**	**5.74**	**0.46**§	....	**0.57**	**38**
Pulp										
Girard:										
Red‖......	1	24.91	....	0.20	2.67	5.96	0.18	0.32	0.49	..
White¶....	1	21.15	....	0.28	2.46	6.06	1.04	0.34	0.51	..

* Cc. *N*/10 acid per 100 grams of fruit. † 3 samples. ‡ Alcohol precipitate. § 1 sample. Pulp 85.54, skin 4.06, seeds 10.40; fiber in pulp 1.28%. ¶ Pulp 88.71, skin 3.65, seeds 6.64; fiber n pulp 1.15%.

COMPOSITION OF AUSTRIAN CURRANTS (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total *	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Red:										
Min...	12.8	5.8	8.0	1.7	2.8	1.1‡	1.6‡	0.1§	0.08	0.59
Max..	17.4	6.9	10.6	2.5	6.9	1.2‡	2.8‡	0.1§	0.12	0.73
White:										
Min...	15.1	7.4	8.9	2.0	4.4	1.9	2.5	0.6§	0.11	0.55
Max...	16.2	7.5	10.3	2.5	5.3	2.6	2.7	0.6§	0.17	0.65

* As invert. † Phosphoric acid: red 0.10 to 0.14%; white 0.10 to 0.13%. ‡ 3 samples. § 1 ample.

below, chose sadly dissimilar forms of presentation. Kremla[1] gives results in percentage of the juice, Einecke[2] in grams per 100 grams of the fruit, and Windisch and Schmidt[1] in grams per 100 cc. of the juice.

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[1] Z. Nahr. Hyg. Waar. 1892, **6**, 483.

[2] Landw. Vers.-Stat. 1897, **48**, 131.

COMPOSITION OF CURRANT JUICE

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Ash, total	Ash, alk.*
Kremla:	9								
Min....		1.040	9.90	0.25	2.11	4.61	....	0.36	..
Max....		1.064	15.70	0.71	3.33	8.22	....	0.76	..
Aver....		**1.052**	**12.71**	**0.44**	**2.58**	**6.91**	....	**0.52**	..
Einecke:	24								
Min.† ..		.....	7.62	0.06	1.60	4.22	0.04	0.37	..
Max.†...		.....	13.08	0.77	2.68	9.16	0.08	0.70	..
W. and S.:	16								
Min.‡...		1.036	9.31	0.20	1.78	5.27	....	0.37	38
Max.‡...		1.056	14.56	0.50	2.37	9.45	....	0.58	59
Aver.‡...		**1.045**	**11.65**	**0.34**	**2.11**	**6.90**	....	**0.48**	**49**

* Cc. $N/10$ acid per 100 cc. of juice. † Pomace 15 to 44%. ‡ Tannin 0.08 to 0.10, aver. **0.09**%.

Composition of Currant Seeds.—As analyzed by Alpers,[2] the seeds contain: water 11.42, protein 14.92, fat 23.64, nitrogen-free extract 24.41, fiber 22.83, and ash 2.78 per cent.

Fatty Oil of Seed.—The values of the oil expressed from the seed by Alpers[2] follow: specific gravity at 15° C. 0.9288, refractive index at 25° C. 1.4772, solidifying point below −20° C., saponification number 194.5, iodine number (Hübl) 159.8, Reichert-Meissl number 0.55, Polenske number 0.5, Hehner number 95.59, acid number 12.9, and unsaponifiable matter 0.64 per cent. Obviously the oil must be classed with the drying group.

Seeds of Norwegian red currants, examined by Jermstad,[3] yielded 20.4 per cent of fat soluble in ether with the following values: specific gravity at 15° C. (recalculated) 0.9343, refractive index at 25° C. 1.4783, saponification number 193.3, iodine number 176.3, ester number 190.2, acid number 3.1, and unsaponifiable matter 1.8 to 2.3 per cent of which 1 per cent was phytosterol. The chief fatty acid of the glycerides was linoleic; about 5 per cent of palmitic and stearic acids and small amounts of oleic and linolenic acids were also present.

Respiration.—Gore,[4] operating with 2 consecutive day's runs of a single variety, noted a maximum evolution of 56 mg. of carbon dioxide per kilo per hour at 30.2° C. and a minimum of 5 mg. at 0.8° C.

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[1] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[2] Ibid. 1916, **32**, 499.

[3] J. pharm. chim. 1931, [8], **13**, 243.

[4] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

Acids.—Truchon and Martin-Claude,[1] Kunz and Adam,[2] Chauvin, Joulin, and Canu,[3] and Muttelet [4] agree in their conclusion that *citric acid* is the only acid present in red and white currants in appreciable amount. Bigelow and Dunbar,[5] who review the literature, report determinations by Fitzgerald and by Dunbar showing, in the variety Prince Albert, citric acid 3.37 and *malic acid* 0.71 per cent, in other varieties citric 1.98 to 2.58 together with malic up to 0.11 per cent or none.

Mineral Constituents.—Analyses made at the Massachusetts Agricultural Experiment Station [6] and compiled by Haskins follow, the results being in percentages of the fresh fruit:

	Water	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5
	%	%	%	%	%	%	%
Red	87.1	0.41	0.19	0.02	0.08	0.03	0.09
White	....	0.59	0.31	0.02	0.10	0.03	0.11

Minor Mineral Constituents. *Iron.*—Red currants 7.0 mg. per kilo, fresh basis (Peterson and Elvehjem).[7]

Aluminum.—Red currants 15, white currants 28 mg. per kilo, dry basis (Bertrand and Lévy).[8]

Zinc.—Red currants 2 mg. per kilo, fresh basis (Bertrand and Benzon).[9]

BLACK CURRANT

Ribes nigrum L.

Fr. Groseille noire. Sp. Grosellero negro. It. Ribes nero.
Ger. Schwarze Johannisbeere.

This European berry is not extensively grown in the United States, although it makes jams and jellies of peculiarly delicious flavor and the plant is of vigorous growth, the secretion of the glands repelling the currant worm.

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[1] Ann. chim. anal. 1901, **6**, 85.

[2] Z. Unters. Nahr.-Genussm. 1906, **12**, 670.

[3] Mon. sci. 1908, **69**, 449.

[4] Ann. fals. 1909, **2**, 383.

[5] J. Ind. Eng. Chem. 1917, **9**, 762.

[6] 1919, Spec. Bul.

[7] J. Biol. Chem. 1928, **78**, 215.

[8] Compt. rend. 1931, **192**, 525.

[9] Bul. soc. hyg. aliment. 1928, **16**, 457.

MACROSCOPIC STRUCTURE.—The *calyx* is about 7 mm. long (longer than in red currant) with reflexed lobes. Numerous hairs clothe the outer surface of the calyx lobes, also the inner surface at the tip, but none occur on the calyx throat, the petals, or the style, all of which are hairy in the gooseberry. The styles are united for at least three-fourths their length.

MICROSCOPIC STRUCTURE.—Meyen[1] describes the glands on the leaf, which are like those on the fruit, Lampe[2] describes the pericarp, and Winton[3] pictures a gland.

Calyx.—The *hairs* are thin-walled, crooked, blunt-pointed, up to 600 μ long, resembling those of the raspberry.

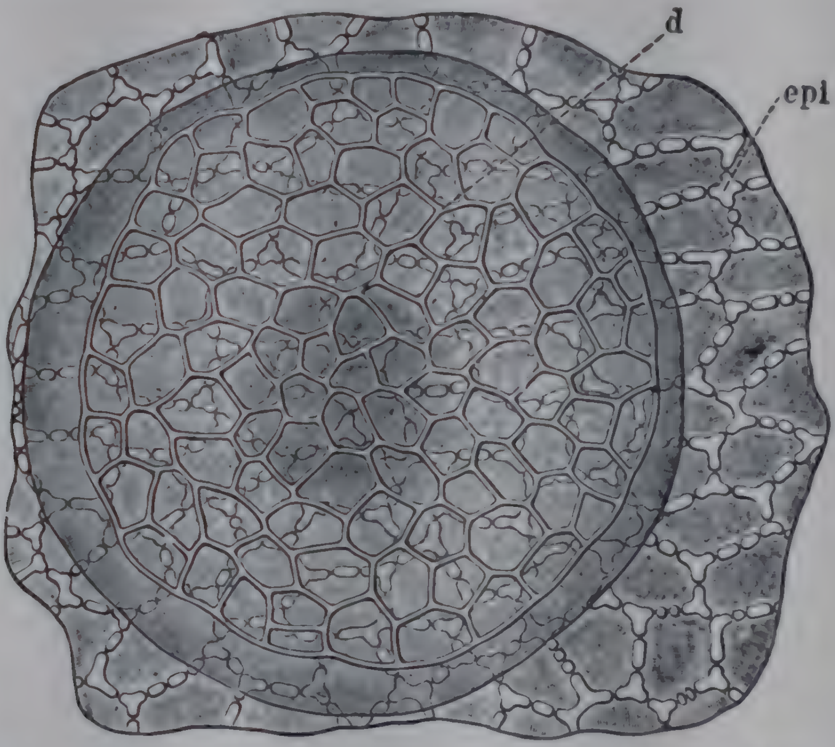

FIG. 191.—Black Currant. *epi* epicarp with *d* gland in surface view. × 160. (A.L.W.)

Pericarp (Fig. 191).—The structure is like that of the red currant except that *volatile oil glands* (*d*) occur on the epicarp (*epi*). These are disk-shaped, often exceeding 150 μ in diameter, consisting of a single layer of cells on a short several-celled stalk. As noted by Meyen, the yellow secretion of essential oil is in the cavity formed by the separation of the cuticle from the cells. Glands of like character occur on the hop plant. Because of the contents of these glands, leaves and fruit have a characteristic spicy odor.

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[1] Secretionsorgane der Pflanzen, Berlin, 1837.

[2] Naturwiss. 1886, **59**, 295.

[3] Z. Unters. Nahr.-Genussm. 1902, **5**, 785; Connecticut Agr. Exp. Sta. Rep. 1902, p. 288.

Spermoderm, Endosperm, and Embryo.—As in red currant.

CHIEF STRUCTURAL CHARACTERS.—Fruit black. Calyx 7 mm. long, hairy except in the throat. Styles smooth. Seeds as in red currant.

Calyx hairs thin-walled, crooked, blunt. Epicarp with disk-shaped glands. Otherwise as in red currant.

CHEMICAL COMPOSITION.—In the fruit, Kulisch[1] found: water 79.00, acids as citric (recalculated) 3.76, invert sugar 9.45, ash 0.951, potash (K_2O) 0.343, lime (CaO) 0.156, magnesia (MgO) 0.050, and phosphoric acid (P_2O_5) 0.132 per cent.

Analyses of the pulp of 2 samples of Austrian black currant by Hotter[2] show the following range:

COMPOSITION OF BLACK CURRANT (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Min....	20.7	7.1	14.1	2.3	7.3	3.3	4.0	0.2	0.33	0.63
Max....	20.9	8.1	15.2	3.4	7.9	3.5	4.4	0.4	0.41	0.87

* As invert. † Phosphoric acid 0.12 to 0.15%.

Respiration.—Gore,[3] working with 3 consecutive day's runs, noted a maximum evolution of 163 mg. of carbon dioxide per kilo per hour at 30.6° C. and a minimum of 9 mg. at 1.2° C.

Acids.—Truchon and Martin-Claude[4] and Chauvin, Joulin, and Canu[5] report only *tartaric acid.* Muttelet[6] found *citric acid* together with only a trace of tartaric acid; later[7] he found 3.50 per cent of citric acid. Results by Guillaume and Adnot[8] show that the maximum content of citric acid by Muttelet's method occurs in the half-ripe fruit. In the fully ripe fruit about 3 per cent is present.

Carbohydrates.—Guillaume and Adnot[8] found that the average sugar content at maturity was a little less than 2 per cent, increasing to over 4 per cent during over-ripening.

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[1] Z. angew. Chem. 1894, p. 148.

[2] Z. landw. Versuchsw. 1906, **9**, 747.

[3] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[4] Ann. chim. anal. 1901, **6**, 85.

[5] Mon. sci. 1908, **69**, 449.

[6] Ann. fals. 1909, **2**, 383.

[7] Ibid. 1922, **15**, 453.

[8] Ibid. 1933, **26**, 75.

AMERICAN GOOSEBERRY

Ribes hirtellum Michx. = *R. oxycanthoides* not L.

The description which follows is of the Downing, probably a hybrid with the European gooseberry (*R. Grossularia* L.).

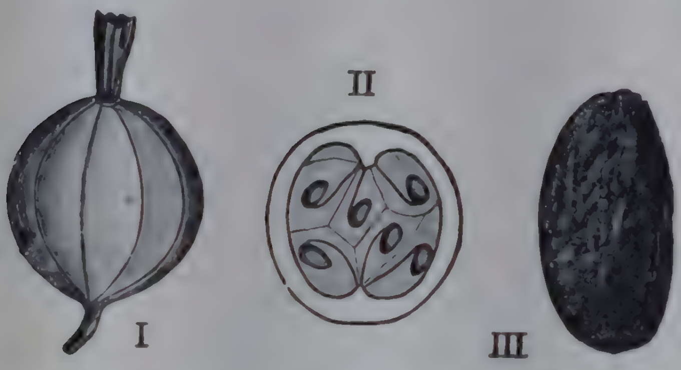

Fig. 192.—American Gooseberry. I whole fruit. × 1. II fruit with seeds in cross section. × 1. III seed deprived of gelatinous coat. × 8. (A.L.W.)

MACROSCOPIC STRUCTURE.—The reddish *berry* (Fig. 192, I) is smooth, 1 to 2 cm. in diameter, being larger than red currant with longer calyx (6 mm.) and style. Except for the throat, which is densely pubescent (Fig. 193), and the apex with a few short hairs, the calyx is nearly smooth. *R. hirtellum* is stated by Rehder[1] to have glabrous sepals and rarely stalked glands on the fruit. The two styles are densely pubescent. Prickles are absent on the fruit, although it is quite possible that they may occur on some hybrids with the European species.

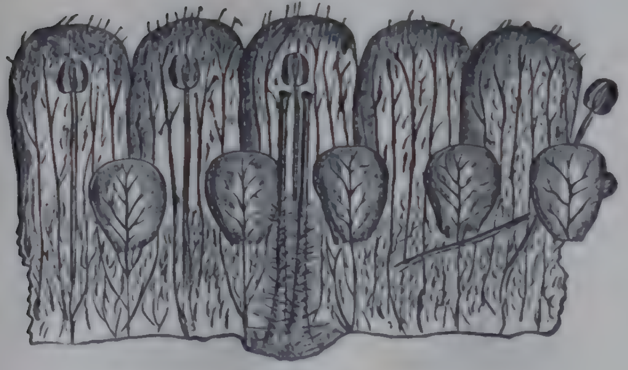

Fig. 193.

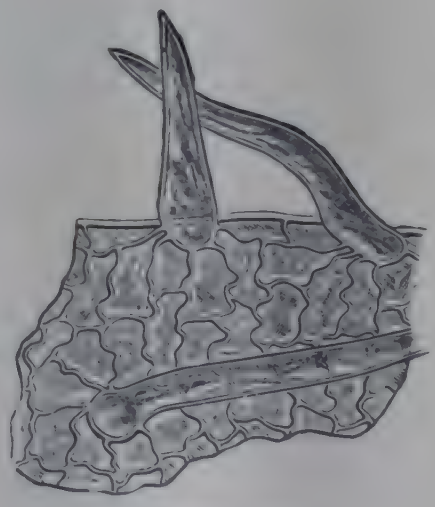

Fig. 194.

Fig. 193.—American Gooseberry. Floral parts. × 5. (A.L.W.)
Fig. 194.—American Gooseberry. Epiderm with hairs from margin of calyx. × 160. (A.L.W.)

The *seed* (Fig. 192, II, III) is larger than the currant seed, owing chiefly to the thicker outer (gelatinous) spermoderm which reaches

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[1] Bailey: Stand. Cycl. Hort., New York, 1922.

2 mm. Freed from this outer coat, the seeds of the two are about the same size, although the gooseberry seed is a little narrower and more terete.

MICROSCOPIC STRUCTURE. Perianth (Fig. 193).—After bleaching with Labarraque solution and staining, the withered floral parts are readily studied. A prominent *midvein* is present in each calyx lobe and petal. About four *secondary veins* parallel with the midvein are also present in each calyx lobe.

The *epidermal cells* of the calyx are somewhat elongated, arranged end to end in rows; at the apex the walls are wavy and short hairs are present (Fig. 194). The *hairs* on the calyx throat are straight and vary up to 1 mm. (Fig. 195). All the hairs have thin walls.

Pericarp.—The *epicarp* and *hypoderm* differ little from those of the red currant, but the *mesocarp cells* are larger, reaching 500 μ, and are separated, except in the inner part, by chains of small cells (50 μ). Crystal rosettes abound in the inner part and occur also in the outer part. The walls of the cells of the *endocarp* are exceedingly thin and not sclerenchymatized.

Chief Structural Characters.—Fruit 1 to 2 cm., globular, reddish. Calyx (6 mm.) persistent, densely pubescent in throat, sparingly at tip. Styles pubescent.

Calyx hairs thin-walled, up to more than 1 mm. Mesocarp cells large (500 μ), separated by chains of small cells in outer part; crystal rosettes numerous; endocarp thin-walled (distinction from red currant). Otherwise as in red currant.

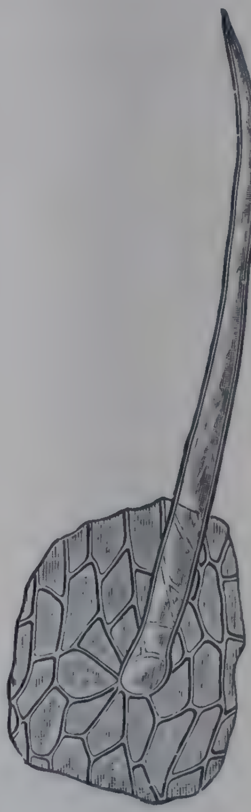

Fig. 195.—American Gooseberry. Epiderm with hair from throat of calyx. × 160. (A.L.W.)

CHEMICAL COMPOSITION.—See European Gooseberry.

EUROPEAN GOOSEBERRY

Ribes Grossularia L.

Fr. Groseille verte. Sp. Uva espín. It. Uva spina.
Ger. Stachelbeere.

Gooseberries as grown in England and continental countries often reach several centimeters in diameter and are of delicious flavor. The wild form occurs in parts of Europe, Asia, and northern Africa. Owing to a mildew, exotic varieties do not thrive in the United States so well as those derived from native species, or hybrids of these with the European species.

MACROSCOPIC STRUCTURE.—The *berry* is usually larger than the American gooseberry, but is chiefly distinguished by the presence of soft prickles.

MICROSCOPIC STRUCTURE.—Except for the presence of *prickles* (Fig. 196), the structure is like that of the American gooseberry. Some of the prickles are blunt-pointed, others have a globular head suggesting that they are glandular in their nature. They often exceed 2 mm. in length. The epidermal cells are elongated quadrilateral, arranged end to end in rows, passing at the base into the isodiametric polygonal cells of the *epicarp*.

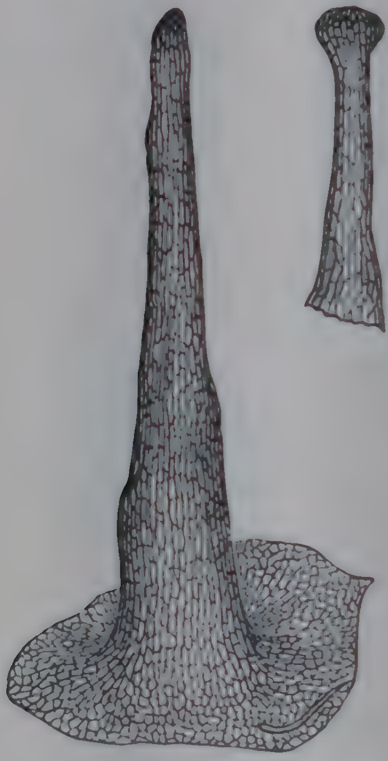

FIG. 196.—European Gooseberry. Prickles with and without globular head. × 32. (A.L.W.)

CHIEF STRUCTURAL CHARACTERS.—As in the American gooseberry, except for the presence of prickles.

CHEMICAL COMPOSITION.—Summaries of analyses by Kulisch,[1] Ystgaard,[2] and Olig[3] are tabulated on the next page.

Analyses by Hotter[4] of the pulp of 8 samples of Austrian gooseberries, not strictly comparable with those in the foregoing table, gave as follows: total solids 11.9 to 15.1, insoluble solids 4.0 to 6.7, extract 8.3 to 11.6, total sugars as invert 3.3 to 7.4, dextrose 1.2 to 3.6, levulose 2.1 to 3.8, sucrose 0.1 to 0.6, acids as malic 1.5 to 2.3, tannin 0.06 to 0.12, total ash 0.45 to 0.67, and phosphoric acid 0.06 to 0.09 per cent.

Composition of Gooseberry Juice.—Analyses of the juice of European berries by Einecke[5] and by Windisch and Schmidt[6] appear on the next page. No data are available on the difference in composition of the juice expressed from cooked and uncooked berries.

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[1] Z. angew. Chem. 1894, p. 148.

[2] Tids. Norske Landbr. 1902, **9**, 125.

[3] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

[4] Z. landw. Versuchsw. 1906, **9**, 747.

[5] Landw. Vers.-Stat. 1897, **48**, 131.

[6] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

Composition of European Gooseberry

	Samples	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Pentosans	Fiber	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	%	cc.
Kulisch:	2									
Min...		14.90	0.88	1.50	7.31	....	....	....	0.44	..
Max...		15.30	0.89	1.83	7.67	....	....	....	0.56	..
Ystgaard:	1	10.48	....	1.57†	5.62		0.57	1.17	....	..
Olig:	5									
Min....		9.95	....	1.87	2.66	0.10	....	....	0.41	28
Max...		14.17	....	2.07	6.93	0.27	....	....	0.47	39
Aver...		**12.00**‡	....	**1.95**	**4.87**	**0.18**	....	....	**0.43**	**33**

* Cc. N/10 acid per 100 grams fruit. † Citric acid 0.66, malic acid 0.62%. The form in which the total acid is calculated is not stated. ‡ Insoluble solids 3.29 to 4.90, aver. **3.98**%.

Composition of Gooseberry Juice

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Einecke:†..	15									
Min.....		.....	7.85‡	0.15‡	0.97	3.99	0.01§	......	0.31‡	
Max.....		.....	13.16‡	0.63‡	1.55	9.02	2.64§	......	0.45‡	
W. and S.:‖	19									
Min.....		1.036	9.26	0.16	0.82	5.72	0.00	0.07¶	0.32	32
Max....		1.057	14.69	0.49	1.69	8.61	0.83	0.09¶	0.60	61
Aver....		**1.043**	**11.05**	**0.32**	**1.16**	**6.58**	**0.38**	**0.08**¶	**0.42**	**43**

* Cc. N/10 acid per 100 cc. juice. † Results in grams per 100 grams of fruit. Pomace 11.39 to 35.03%. ‡15 samples. § 18 samples. ‖ Results in grams per 100 cc. of juice. ¶ 3 samples.

Acids.—Ystgaard,[1] Kunz and Adam,[2] and Bigelow and Dunbar[3] agree that both *citric* and *malic acids* are present, citric predominating. The last-named authors quote analyses by Clark and by Fitzgerald and Dunbar showing citric 1.72 to 2.63 and malic 0.28 to 2.08 per cent in American varieties. Muttelet[4] reports 2.07 and 2.20 per cent of citric acid respectively in red and white gooseberries.

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[1] Loc. cit.

[2] Z. Unters. Nahr.-Genussm. 1906, **12**, 670.

[3] J. Ind. Eng. Chem. 1917, **9**, 762.

[4] Ann. fals. 1922, **15**, 453.

Mineral Constituents.—Wolff[1] gives the following analysis in percentages of the fresh fruit:

Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2
% 0.38	% 0.15	% 0.04	% 0.05	% 0.02	% 0.07	% 0.02	% 0.01

Minor Mineral Constituents. *Iron.*—Berries 4.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Copper.—Berries 0.8 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[3]

Zinc.—Berries 1 mg. per kilo, fresh basis (Bertrand and Benzon).[4]

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[1] Aschenanalysen.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Ibid. 1929, **82**, 465.

[4] Bul. soc. hyg. aliment. 1928, **16**, 457.

FRUITS OF THE ROSE FAMILY

(*Rosaceæ*)

Of the thirteen tribes into which the species of this large and important family are divided, five are represented by species yielding edible succulent fruits as follows: I pomes (*Pomeæ*), II strawberries (*Potentilleæ*), III bramble berries (*Rubeæ*), and IV drupes (*Pruneæ* and *Chrysobalaneæ*). In addition to fruits of the above tribes, the hips of certain species of roses of the tribe *Roseæ* are preserved in some countries (see Rose Hips, Volume I).

I. POMES

(*Pomeæ*)

Pomes, in the generally accepted sense, are rosaceous fruits formed by the consolidation of the receptacle with the one- to five-loculed ovary, usually crowned by the persistent calyx and stamens. The outer fleshy part is believed by some to be calyx tube.

COMPARATIVE MACROSCOPIC STRUCTURE. Flower.—Normally the flower is five-merous with the five sepals, five petals, and (usually) twenty stamens borne at the top of the receptacle. Each of the five locules of the ovary contains two or more ovules but usually some or all fail to develop into seeds.

Fruit (Receptacle and Pericarp).—In the medlar, the crown (sepals and stamens) is as broad as the broadest part of the fruit; in the other pomes it is narrow. All of the pomes are more or less hairy; the apple and pear, however, have hairs only around the stem and calyx. All but the quince and medlar, which are borne at the end of the branches of the same season, have true peduncles. The fruit flesh, except in the apple, contains hard lumps which grit between the teeth, the nature of which is considered below. The endocarp or core varies from a hard layer, 2 mm. thick in the medlar, to a soft thin tissue in the loquat. In the apple, it is tough and parchment-like; in the pear and quince, less strongly developed.

Seed.—The seeds are not very different in the various species excepting the loquat, where they are as large as almonds. The spermoderm is brown and leathery, the perisperm and endosperm white and membranous or, in the loquat, lacking. Fleshy cotyledons and a small radicle make up the embryo.

COMPARATIVE MICROSCOPIC STRUCTURE. Fruit.—In all the species but the medlar, the *epiderm* in surface view clearly shows the original thicker cell walls of the mother cells and the thinner walls dividing the mother cells into daughter cells. Large cells, up to more than 50 μ, characterize the apple (in the crab apple they are smaller) and the loquat; smaller cells, up to about 35 μ, the pear, quince, and medlar.

Usually the *hairs* of the apple are very thin-walled, while those of the pear, quince, and loquat are very thick-walled, and of the medlar are intermediate, the lumen in the latter case equaling or exceeding the walls. Kinky hairs occur in all, but in the pear moderately wavy hairs predominate, except at the two ends.

Numerous *stone cells* are present in the fruit flesh of all the pomes, except the apple which has none or sometimes a few at the stem end. They occur in large groups in the pear and quince, singly or in small groups in the medlar, and usually singly in the loquat. Except in the medlar, the stone cells have thick walls and narrow lumen. Thin-walled *parenchyma*, more or less elongated, radiates from each stone cell group in the pear and quince; the parenchyma cells in other parts of the main fruit flesh of these two fruits and throughout the main fruit flesh of the other pomes are large and sac-shaped, containing starch grains which disappear at full maturity.

The inner fruit flesh consists of *spongy parenchyma*. Here and there throughout the main fruit flesh and especially in the inner fruit flesh, *oxalate crystals* are present. In the apple, medlar, and loquat, they mostly form crystal rosettes; in the pear and quince they mostly occur as single monoclinic crystals or twins.

A mass of small, thick-walled stone cells makes up the *endocarp* of the medlar, replaced by thick-walled fibers in the apple, thinner-walled fibers in the pear and quince, and exceedingly thin-walled, elongated cells in the loquat.

The apple, pear, and quince have masses of *suture hairs* about the slits, formed by the opening of the endocarp sutures into the central cavity, also in cracks formed in other parts of the endocarp. These are either (1) warty, in which case they are always jointed and often branched, or (2) smooth, either jointed or unicellular. Some of the joints of the warty hairs of the apple, less often of the pear, may have sclerenchymatous thickenings, but such have not been noted in hairs of the quince. The smooth hairs are thin-walled in the apple; many are also thin-walled in the pear and quince, but in addition there are thick-walled, unicellular, kinky forms like those on the epiderms of the same fruits.

Spermoderm.—As seen in surface view, the cells of the *outer epiderms* of the apple and medlar are elongated; of the pear, quince, and loquat, isodiametric polygonal. Seen in cross section, those of the apple, loquat, and medlar are low; of the pear and quince high, that is radially elongated. Secondary mucilaginous thickening is more or less evident in all the species and tertiary sclerenchymatous thickening in the apple and pear, but not in the quince or loquat.

All the species but the loquat agree closely in the structure of the remaining layers of the spermoderm, as described under apple, the fifth layer being of special interest because of the presence of numerous minute starch grains.

Perisperm.—Not evident in the loquat; in the other species it forms a layer of compressed cells.

Endosperm.—*Aleurone cells*, several thick, and a layer of *compressed cells* occur in all but the loquat.

Embryo.—*Aleurone grains*, with globoids, and *fat* are the visible contents, except in the loquat which is unique among rosaceous fruits in that the contents are *starch grains* of the tapioca type.

COMPARATIVE CHEMICAL COMPOSITION.—In pomes, as well as various other fruits, progressive disappearance of starch, increase in sugars, and decrease in acids have been abundantly demonstrated. *Reducing sugars* are present in greater amount than *sucrose*. Reif[1] finds *sorbitol* in the common pomes. *Malic acid* appears to be the only acid of the apple and quince; *citric acid* is present in some varieties of pear and may be the chief or sole acid. *Tannin* and other astringent substances occur in variable amounts and add piquancy. The *odorous constituents* of the apple have been isolated. *Pectins* are particularly abundant. Lack of adequate results on fiber, or even insoluble solids in the pulp, leaves uncertain the influence of the stone cells of the pear and quince on these determinations.

Seeds of pomes are oily, with rather high iodine number. *Amygdalin* is present.

APPLE

Pyrus (or *Pirus*) *Malus* L. = *Malus communis* DC. = *M. Malus* Brit.

Fr. Pomme. Sp. Manzana. It. Pomo. Ger. Apfel.

Most cultivated varieties of apples are believed to have been derived from the wild hairy apple (var. *pumila* Henry = var. *mitis* Wallr.) of western and central Europe. Only a few owe their origin to the smooth wild apple (var. *sylvestris* L. = var. *austera* Wallr.) of southern and eastern Europe and southwestern Asia.

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[1] Z. Unters. Lebensm. 1934, **68**, 179.

The cultivation of the apple antedates history; the number of varieties is legion; the distribution is over all temperate regions. Long search for a seedless and coreless apple has not yet been successful. In temperate regions the apple stands first alike as a dessert and cooking fruit, and is second only to the grape as a source of juice for use fresh or fermented. Dried and canned apples, apple jelly, and "apple butter" are important commercial products. Cider vinegar is preferred in the United States to all other kinds.

MACROSCOPIC STRUCTURE.—Apple blossoms have normally five pointed calyx lobes, five rounded petals (pink beneath), and twenty stamens, all borne on the consolidated receptacle and ovary which has five locules, each with two ovules. The dried-up calyx, covered commonly on both sides with a felt of hairs, persists on the fruit as do the stamens.

The distinctive characters of the *fruit* are the depression at each end, the greater breadth of the depression at the stem end than at the calyx end regardless of form (the reverse in the pear), and the absence of stone cells in the fruit flesh. The skin over the body of the fruit is smooth and lustrous or in the russet varieties dull and rough to the touch. Soft hairs, seen under a lens, occur not only on the calyx and stem but on the skin of the fruit about them.

Cross sections of the fruit show ten main bundles running through the fruit flesh, and longitudinal sections show that each of these forms a loop, beginning at the stem and ending at the calyx. From these, secondary bundles branch off toward the periphery, and from the stem other primary bundles with branches pass into the lower part of the fruit.

The *bundle zone* is commonly regarded as the dividing line between the receptacle and pericarp. This cannot be strictly true as the bundles unquestionably belong to the receptacle and must have tissues within them also belonging to the receptacle, since bundles never occur in an epiderm. It is indeed quite possible that only the very innermost part of the fruit flesh is mesocarp, a thin mesocarp being not unusual in the family, for example in the strawberry.

The *core* consists of the parchment-like endocarp about the five locules, each with two seeds or less. The endocarp often splits at the center sutures, thus connecting the locules with each other and the central cavity. On the torn edges of the suture, also in cracks of the endocarp, a mass of hairs often appears, forming felt-like patches.

The *seeds* are brown, obovate, somewhat flattened, pointed at the base and rounded at the apex. A leathery spermoderm, a thin colorless perisperm, and a somewhat thicker endosperm form skins about the embryo. The cotyledons are oval and fleshy; the radicle is minute.

MICROSCOPIC STRUCTURE.—The first comprehensive study of the pericarp and seed was made by Malfatti.[1] Howard [2] studied the starch of the green pericarp and its disappearance on ripening.

Stem.—Cross sections show the following zones: (1) *epiderm* with thick cuticle, (2) typical *cork cells,* several thick, (3) *collenchyma* of small cells passing into (4) large porous cells of the *cortex* with intercellular spaces at the angles, (5) *stone cells,* often radially elongated, (6) large *bast fiber bundles* with stone cells in medullary rays, (7) *phloem,* (8) *cambium,* (9) *xylem* with spiral and spirally reticulated vessels and tracheids, also thin-, porous-walled medullary rays, and (10) *pith* consisting largely of thick-walled stone cells replacing thin-walled parenchyma.

Calyx.—Owing to the dense felt of hairs on both the outer and inner surface and the dark color, other details of structure are obscured. The *hairs* are like those in the stem and calyx depression described below.

Fruit (Figs. 197 and 198).—Since this is the consolidated receptacle and pericarp, the terms epicarp and mesocarp are not applicable; in their place epiderm and fruit flesh are used. The four layers, as seen in surface view, are as follows: (1) *epiderm* (*epi*) of thick-walled mother cells divided by thin walls into daughter cells (longest diameter up to 70 μ), interrupted in russet spots by cork cells, also about the calyx and stem by long (up to 2 mm.), narrow, flattened, thin-walled, often kinky hairs; (2) *hypoderm* (*hy*) of isodiametric cells, several thick, with thickened, beaded walls and prominent intercellular spaces at the angles; (3) *fruit flesh* of large sac-shaped cells (p^1), in the innermost part irregular with numerous intercellular spaces (p^2), fibro-vascular bundles accompanied by elongated sclerenchyma cells (*st*) and fibers (*f*), and in the stem end occasional stone cells (st^1) of various forms; and (4) *endocarp* (*end*) of crossing sclerenchyma fibers and occasional crystal fibers (cr^2).

The cells of the *epiderm* are more or less quadrilateral, often with occasional pores. In cross section, a thick cuticle is evident. The color of the fruit is due to the contents of the epiderm and hypoderm. In green fruit this consists of chlorophyl grains, in red fruit of coloring matter in solution which becomes green with alkali. The contents give the tannin reaction with ferric chloride.

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[1] Z. Nahr. Unters. Hyg. Waarenk. 1896, **10**, 265.

[2] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **94**, 89.

The *fruit flesh* includes outer fleshy tissues belonging to the receptacle and inner tissues belonging to the pericarp.

Carré and Horne,[1] who carried out histological studies of the tissues parallel with the chemical studies on pectins by the senior author (see below), state that the *pectins* are in two portions of the walls: (1) the middle lamella and the corresponding layer bounding the intercellular spaces and (2) the cell wall complex. They used ruthenium red to differentiate the wall structure, also various solvents such as ammonium oxalate, and hydrochloric acid followed by potassium hydroxide to dissolve the different forms of pectins, and Schweitzer's reagent to dissolve cellulose. During the early stages, the walls show no differentiation on staining, then the middle lamella expands, forming disks, crescents, and bands of pectin substances which, on the cellulose being dissolved, preserve the original form of the cells. Finally the whole network breaks down into globules.

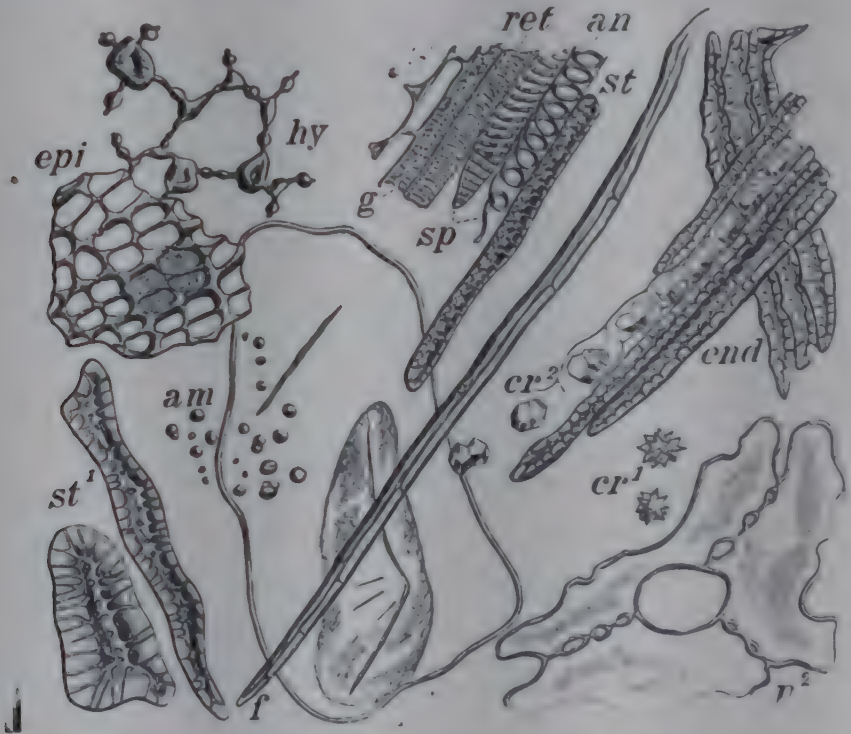

FIG. 197.—Apple. Elements of fruit in surface view. *epi* epiderm; *hy* hypoderm; st^1 stone cells in vicinity of stem; p^1 parenchyma with *am* starch grains; p^2 spongy parenchyma; cr^1 rosette crystals; *g* pitted, *ret* reticulated, *sp* spiral, and *an* annular vessels, *f* bast fiber, and *st* sclerenchyma cell of fibro-vascular bundle; *end* crossing sclerenchyma fibers and cr^2 crystal fiber of endocarp. × 160. (K.B.W.)

Immature apples are characterized by the presence of a large amount of starch in the hypoderm and fruit flesh. The *starch grains* (*am*) occur singly or in small aggregates, the former being globular or ovoid, up to 15 μ or more in length, sometimes with a central cleft. On ripening, the starch gradually disappears. According to Howard, the disappearance begins about the core.

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[1] Ann. Bot. 1927, **41**, 193.

Oxalate crystals (cr^1), mostly in rosettes, less often in monoclinic prisms, occur in the inner fruit flesh. Typical *stone cells*, such as are characteristic of the fruit flesh of the pear and quince, are usually absent in the fruit flesh of the apple but occasionally a few occur in the stem end (st^1). The *fibro-vascular bundles* of the fruit flesh have spiral (*sp*), annular (*an*), reticulated (*ret*), and pitted (*g*) vessels. Accompanying the bundles are rod-shaped, pitted, sclerenchyma cells (*st*) and bast fibers (*f*).

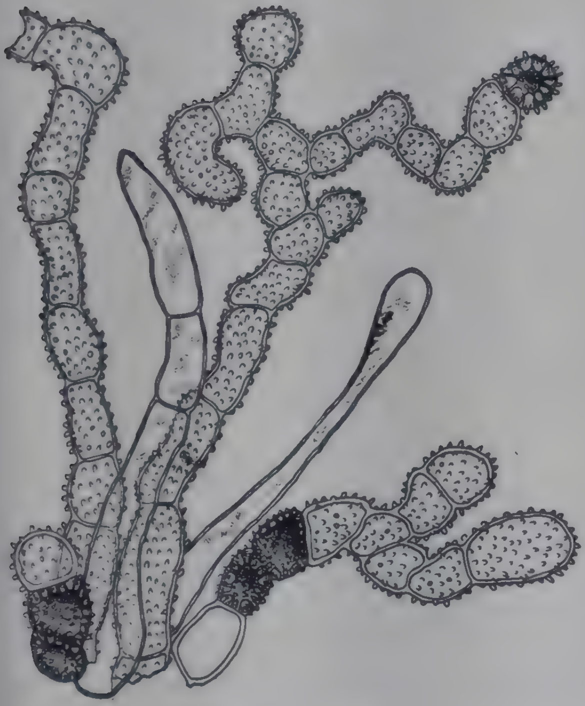

Fig. 198.

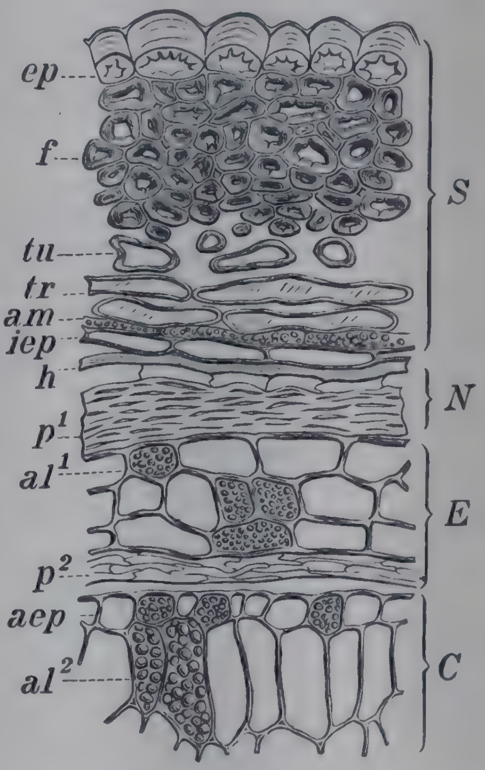

Fig. 199.

Fig. 198.—Russet Apple. Hairs from endocarp suture. × 160. (K.B.W.)

Fig. 199.—Apple. Seed in cross section. *S* spermoderm: *ep* outer epidermis, *f* fibers, *tu* tube cells, *tr* cross cells, *am* starch cells, *iep* inner epiderm. *N* perisperm: *h* hyaline layer, p^1 obliterated cells. *E* endosperm: al^1 aleurone cells, p^2 compressed parenchyma. *C* cotyledon: *aep* outer epiderm, mesophyl containing al^2 aleurone grains. × 160. (K.B.W.)

The *endocarp*, in addition to the crossing sclerenchyma fibers and crystal fibers with monoclinic twins, is characterized by the presence of curious *hairs* of several forms (Fig. 198) in the sutures which open into the central cavity of the fruit, also in cracks of the endocarp. Some are unicellular, blunt-pointed or even enlarged at the end, with thin, smooth walls; others are jointed, the component cells being either warty or smooth and when warty either with thin walls or with thickened and porous sclerenchyma walls. The jointed hairs with warty cells—the more common form—are often branched.

Malfatti distinguishes these suture hairs on the apple from those on the pear by the presence in the apple of sclerenchyma cells, occurring mostly as end members, and their absence in the pear. We find that neither generalization holds true for all specimens. In large well-developed apples of many dessert varieties, the sclerenchyma cells either are entirely lacking or occur rarely and then only as terminals, while in smaller and poorly developed fruit from the same tree they may occur in considerable numbers. It seems to be true, however, that their occurrence in well-developed russet apples (Fig. 198), both as basal and terminal cells, is more common. On the other hand, while in specimens of most varieties of pears, the sclerenchyma cells have not been present, in one variety at least (Glout Morceau), grown in California and shipped east, they occur in abundance as basal, terminal, and intermediate cells.

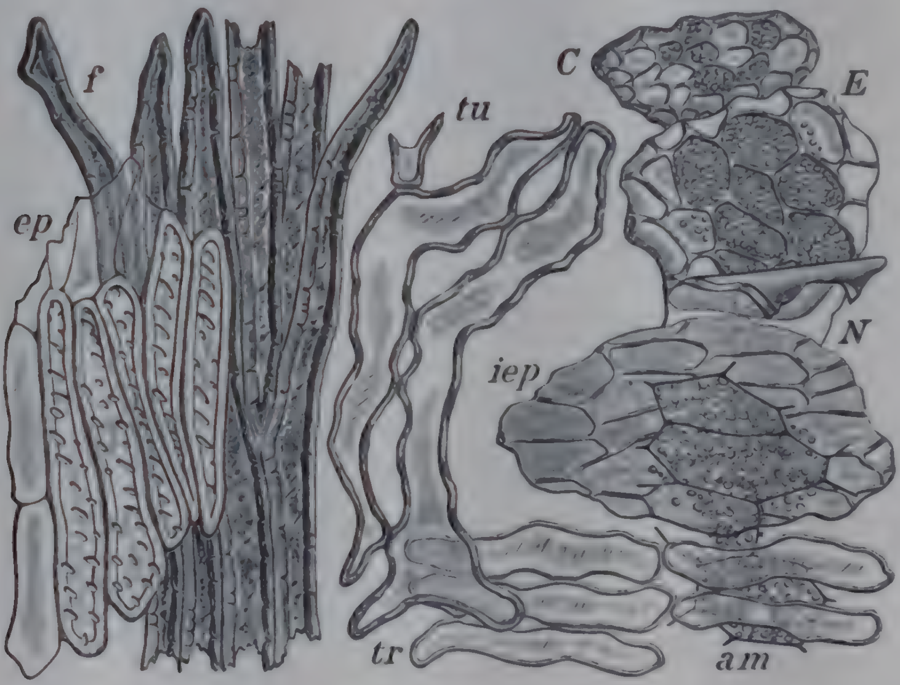

Fig. 200.—Apple. Elements of seed in surface veiw. Spermoderm: *ep* outer epiderm, *f* fibers, *tu* tube cells, *tr* cross cells, *iep* inner epiderm. *N* perisperm. *E* endosperm. *C* outer epiderm of cotyledon. × 160. (K.B.W.)

Spermoderm (Fig. 199, *S*; Fig. 200).—Six well-differentiated layers are present: (1) *outer epiderm* (*ep*) of longitudinally elongated, thick-walled cells with mucilaginous thickening without and sclerenchymatous, diagonal porous thickening adjoining the lumen; (2) *subepiderm* (*f*) of broad, thick-walled brown sclerenchyma fibers with diagonal pores; (3) *tube cells* (*tu*), in loose contact, with brown walls; (4) *cross cells* (*tr*), also in loose contact; (5) *starch parenchyma* (*am*) of exceedingly thin-walled, polygonal, somewhat transversely elongated cells, containing starch grains about 3 μ in diameter; and (6) *inner epiderm* (*iep*) differing from the last in that the walls are thicker, brown, and starch is absent.

Perisperm (Figs. 199 and 200, *N*).—A layer with colorless outer membrane (*h*), staining yellow with chlorzinc iodine, and exceedingly thin radial walls and inner *compressed cells* (p^1), staining blue, form the perisperm.

Endosperm (Figs. 199 and 200, *E*).—This consists of an *aleurone layer* (al^1), three to six cells thick, with minute aleurone grains, and compressed cells (p^2).

Embryo.—The bulky cotyledons (Figs. 199 and 200, *C*) have small isodiametric *epidermal cells* (*aep*) and radially elongated *inner cells*, all containing aleurone grains (al^2), reaching a maximum of 10 μ, with one or more large globoids.

CHIEF STRUCTURAL CHARACTERS.—Fruit various in size, shape, and color; calyx (hairy on both sides) and stem in depressions; epiderm hairy about stem and calyx, elsewhere smooth (or rough in russet varieties); fruit flesh crisp; endocarp parchment-like forming five locules. Seed obovate; spermoderm brown, leathery; perisperm and endosperm thin, white; embryo with fleshy cotyledons and small radicle.

Epidermal cells up to 70 μ (larger than in pear), hairs thin-walled, kinky; hypoderm cells isodiametric; fruit flesh cells largely sac-shaped, containing starch (15 μ) when immature, stone cells only in stem end (in other common pomes throughout fruit flesh), oxalate crystals mostly rosettes; endocarp fibers strongly thickened, crystal fibers with twin crystals; suture hairs partly smooth, thin-walled, partly warty, jointed, with or without sclerenchyma members. Outer epidermal cells of spermoderm longitudinally elongated (radially elongated in pear and quince), secondary thickening mucilaginous, tertiary thickening sclerenchymatous; fifth layer of spermoderm starchy. Endosperm and cotyledons with small aleurone grains.

CHEMICAL COMPOSITION.—Representative types of American apples, including 5 Summer, 2 Autumn, and 18 Winter varieties, as analyzed by Browne,[1] contained as given in the table on p. 566.

The approximate average amounts of the constituents not given in the table according to Browne are: protein 0.10, oil 0.30, combined malic acid 0.20, starch 0, pentosans 0.50, pectin matter 0.40, lignin 0.40, cellulose 0.90, and undetermined (tannic acid, etc.) 0.30 per cent.

Hotter,[2] in the flesh of 19 samples of Austrian apples, gives results ranging as follows: total solids 13.6 to 26.0, insoluble solids 1.5 to 5.7,

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[1] Pennsylvania Dept. Agr. 1899, Bul. 58.

[2] Z. landw. Versuchsw. 1906, 9, 747.

Composition of Flesh of 25 Varieties of Apples (Browne)

	Water	Solids	Malic acid*	Sugars, total	Invert sugar	Sucrose	Ash
	%	%	%	%	%	%	%
Summer:							
Red Astrachan	84.70	15.30	1.11	10.20	6.67	3.53	0.37
Early Harvest	83.82	16.18	0.87	11.08	7.24	3.84	0.31
Yellow Transparent	86.17	13.83	0.84	9.89	7.84	2.05	0.27
Early Strawberry	84.42	15.58	0.76	9.45	5.34	4.11	0.28
Sweet Bough	85.18	14.82	0.10	10.49	7.51	2.98	....
Autumn:							
Bitter-sweet	85.70	14.30	0.38	11.59	7.97	3.62	0.19
Fall Rambo	83.86	16.14	0.61	11.52	6.60	4.92	0.25
Winter:							
Baldwin	80.36	19.64	0.65	14.51	7.70	6.81	0.27
King	84.30	15.70	0.48	11.81	7.94	3.87	0.27
Golden Russet	76.64	23.36	0.70	16.54	11.75	4.79	0.32
Greening	83.20	16.80	0.68	12.38	7.11	5.27	0.26
Ben Davis	85.04	14.96	0.55	10.49	6.90	3.59	0.26
Northern Spy	82.69	17.31	0.60	12.95	9.18	3.77	0.29
Spitzenburgh	81.28	18.72	0.74	13.96	8.56	5.41	0.30
Twenty Ounce	86.54	13.46	0.45	9.87	7.27	2.60	0.17
Jonathan	85.28	14.72	0.52	11.03	7.40	3.63	0.22
Canada Reinette	85.62	14.38	0.51	10.34	6.60	3.74	0.24
Rambo	84.30	15.70	0.36	12.06	10.32	1.74	0.23
Newtown Pippin	82.39	17.61	0.80	12.49	6.36	6.13	0.27
Ewalt	84.36	15.64	0.99	10.77	8.13	2.64	0.26
York Imperial	82.90	17.10	0.46	12.98	8.65	4.33	0.22
Fallawater (Tulpahocken)	84.69	15.31	0.32	11.59	8.51	3.08	0.22
Yellow Bellflower	81.68	18.32	0.74	13.08	8.43	4.65	0.34
Sweet Vandevere	82.25	17.75	0.26	12.66	8.81	3.85	0.30
Bedford Red	84.96	15.04	0.66	10.90	7.40	3.50	0.28
Average	**83.57**	**16.43**	**0.61**	**11.91**	**7.92**	**3.99**	**0.27**

* Free acid calulated as malic.

extract 12.1 to 18.0, total sugars as invert 9.5 to 17.4, dextrose 2.5 to 5.6, levulose 6.5 to 11.8, sucrose 1.5 to 6.0, acids as malic 0.3 to 1.0, tannin 0.02 to 0.15, total ash 0.22 to 0.50, and phosphoric acid 0.03 to 0.06 per cent.

Somewhat different constituents were determined by Olig[1] in 5 samples of European apples as shown by the following averages: water-soluble matter 10.82, water-insoluble matter 2.16, acids as malic 0.48, reducing sugars 7.95, sucrose 0.28, total ash 0.26, soluble ash 0.25, alkalinity of ash (cc. normal acid per 100 grams of fruit) 2.41, total phosphoric acid 0.029, and soluble phosphoric acid 0.021 per cent.

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[1] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

Composition of Apple Juice.—A summary of results obtained by Kulisch [1] in the analysis of the juice of 23 varieties of apples follows:

COMPOSITION OF JUICE OF GERMAN APPLES (KULISCH)

	Sp. gr. 17.5° C.	Solids, total	Solids, non-sugar	Acids as malic	Sugars, reducing	Sucrose
		%	%	%	%	%
Min.......	1.0451	11.60	1.33	0.17	6.47	0.75
Max.......	1.0724	18.82	4.65	1.10	11.02	6.27
Aver.......	**1.0594**	**14.83**	**2.91**	**0.64**	**8.71**	**3.21**

Thompson and Whittier,[2] in studies of juices of apples, pears, grapes, and strawberries, observed an increase in average molecular weight of solids, also in osmotic pressure (excepting the strawberry), toward maturity. Ionization (excepting the grape) was shown by the depression of the freezing point to be high. No appreciable or uniform change in the amounts of ash or acid was noted. They tentatively advance the theory that invert sugar or a monosaccharide is first formed, later sucrose is formed from invert sugar and starch from dextrose, the reactions being reversible. Since dextrose is more subject to loss by respiration, levulose later predominates.

The juice of a large number of American and French varieties of apples, grown in the Arlington (Virginia) orchard of the Bureau of Plant Industry, was analyzed by Caldwell,[3] the results on 7 varieties being given on the following page.

The varieties of the cider type, such as Amère du Surville, are characterized by their high astringency, a quality which is quite as important for flavor as sugar and acid. The author stresses the importance of the *acid-astringency-sugar ratio.*

The following analyses of filtered juice of Rome Beauty, Russet, and Northern Spy apples were obtained by Carpenter and Smith: [4] *p*H 3.37, 3.37, and 3.54; specific gravity at 20° C. 1.054, 1.0706, and 1.054; refractive index at 20° C. 1.3534, 1.3596, and 1.3534; solids by Schön-

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[1] Landw. Jahrb. 1892, **21**, 427.

[2] Delaware Agr. Exp. Sta. 1913, Bul. **102**.

[3] J. Agr. Res. 1928, **36**, 289, 391, 407.

[4] Ind. Eng. Chem. 1934, **26**, 449.

Composition of Apple Juice of Different Varieties and Years (Caldwell)

	Solids	Acids as malic	Sugars,* total	Sugars,* reducing	Sucrose*	Astringency		
						Total	Tannin	Non-tannin
	%	%	%	%	%	%	%	%
Baldwin:								
1920	12.96	0.63	10.11	8.72	1.39	....	....	....
1922	.....	0.57	10.53	7.36	3.17	0.09	0.03	0.06
1923	16.02	0.64	14.96	9.40	5.56	0.13	0.05	0.09
1924	.....	0.43	11.48	7.24	4.24	0.12	0.03	0.10
1925	.....	0.42	10.19	6.76	3.43	0.10	0.03	0.06
McIntosh:								
1920	.....	0.42	9.79	8.13	1.66	....	....	....
1922	11.36	0.57	9.42	8.03	1.39	0.10	0.05	0.04
1923	13.44	0.65	11.34	8.00	3.34	0.12	0.06	0.06
1924	.....	0.42	10.40	7.04	3.36	0.07	0.03	0.04
1925	11.84	0.37	9.41	6.66	2.75	0.10	0.04	0.06
Delicious:								
1920	.....	0.25	10.60	9.55	1.05	....	....	....
1921	.....	0.31	11.69	7.39	4.30	....	....	....
1922	12.46	0.28	10.10	7.28	2.82	0.09	0.04	0.05
1924	.....	0.22	10.22	8.24	1.98	0.08	0.03	0.04
Amère du Surville:								
1922	13.91	0.41	9.92	8.98	0.94	0.34	0.21	0.12
1923	13.21	0.25	11.34	9.70	1.64	0.74	0.42	0.32
1924	.....	0.15	10.98	8.97	2.01	0.44	0.28	0.16
1925	15.87	0.18	12.88	11.06	1.82	0.47	0.21	0.26
Golden Russet:								
1920	12.39	0.48	10.67	10.28	0.39	0.09	0.03	0.06
1922	.....	0.48	12.34	11.01	1.33	0.09	0.02	0.06
1923	15.46	0.61	12.98	9.43	3.55	0.10	0.04	0.06
1924	.....	0.45	11.82	9.00	2.82	0.08	0.03	0.05
Yellow Transparent:								
1922	9.24	0.68	7.90	6.34	1.56	0.19	0.11	0.08
1923	12.17	1.40	9.42	7.35	2.07	0.23	0.09	0.14
1924	9.69	0.44	6.08	5.31	0.77	0.14	0.04	0.10
1925	.....	0.49	7.53	5.92	1.61	0.08	0.03	0.05
Hogg:								
1922	13.14	1.45	9.51	6.80	2.71	0.20	0.08	0.12
1923	14.99	2.26	13.74	8.30	5.44	0.16	0.07	0.08
1924	.....	1.07	10.04	6.11	3.93	0.13	0.07	0.06
All analyses:								
Min	7.63	0.08	6.08	3.37	0.16	0.04	0.01	0.01
Max	18.33	2.26	16.56	11.94	7.03	0.74	0.43	0.32

* As invert sugar.

rock method 13.5, 17.4, and 13.5, solids by drying 13.09, 16.88, and 12.75, protein 0.035, 0.060, and 0.023, volatile acidity calculated as acetic acid 0.04, 0.14, and 0.06, total acidity calculated as malic 0.26, 0.70, and 0.42, levulose 5.76, 4.56, and 5.83, dextrose 3.62, 3.20, and 3.15, sucrose 2.29, 5.63, and 2.22, calcium pectate 0.132, 0.165, and 0.094; tannin 0.012, 0.021, and 0.018, non-tannin astringency 0.066, 0.100, and 0.085, and total astringency 0.078, 0.121, and 0.103 per cent; esters expressed in cc. of $N/10$ KOH per first 200 cc. of steam distillate 0.247, 0.18, and 0.20.

By returning to the non-volatile residue the esters driven off during steam distillation, a concentrate was obtained which, when diluted, resembled closely the original juice.

Composition of Apple Marc.—Bigelow and Gore[1] pared and cored Rhode Island Greening apples, pressed out the juice, washed the pomace thoroughly with cold water, pressing after each addition, and dried the residue at room temperature. Analysis gave the following results: protein 3.43, ether extract 0.74, reducing sugars 1.67, galactans extracted by hot water 12.96, pentosans 24.51, pentosans extracted by hot water 15.50, fiber 30.90 (containing pentosans 2.92), cellulose 40.19 (containing pentosans 5.51), and ash 0.95 per cent. No comment is made on the relation of the pentosans and galactans of the hot water extract to pectins. Accepting recent views on the constitution of pectic acid, the mucic acid obtained in the analysis, from which the percentage of galactans was calculated, was derived in large part from galacturonic acid.

Composition of Apple Seeds.—As analyzed by Huber,[2] the composition of the seeds is shown by the figures given below, in percentages of the dry matter. The air-dry material contained: dry kernels 58.44, dry hulls 33.53, and dry whole seeds 91.97 per cent.

	Protein	Protein,* pure	Amygdalin†	Fat‡	Lecithin§	Sugars‖	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Kernel	52.81	42.60	1.01	32.70	1.25	3.26	2.53	1.47	4.77
Hulls..	11.12	7.66	0.07	8.99	0.51	3.70	13.44	21.98	2.11
Whole.	37.62	27.05	0.67	24.03	0.99	3.42	6.66	8.96	3.79

* Factor 5.55. † Factor 32.7. ‡ Lecithin-free. § Factor 26. ‖ As invert.

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[1] J. Am. Chem. Soc. 1906, **28**, 200.

[2] Landw. Vers.-Stat. 1911, **75**, 443.

Alcohol dissolved four times as much sugar from the kernels and eight times as much from the hulls as water.

Composition of Dried Apples.—Analyses of 3 samples reported by Atwater and Bryant [1] show as follows:

	Water	Protein	Fat	N-f. ext.*	Ash
	%	%	%	%	%
Min........	8.6	1.2	0.1	48.6	1.4
Max.......	47.4	2.5	5.0	86.9	2.7
Aver.......	**28.1**	**1.6**	**2.2**	**66.1**	**2.0**

* Includes fiber.

Composition of Apple Flour.—Zago [2] gives the following analysis of apple flour milled after drying the minced fruit at 55° C.: water 6.29, solids 93.71, pectin 7.04, malic acid 1.44, tannic acid 0.45, reducing sugars 42.46, sucrose 7.84, and cellulose 8.10 per cent.

Changes in Composition During Growth and Ripening.—Investigators who have studied the chemical changes taking place during growth have in most instances continued their work through the stages of ripening, the transition from one to the other being without sharp demarcation. A number have further continued their studies so as to include the changes taking place during storage at different temperatures. In this case also there is a gradual transition from one period to the other, since changes begun while the fruit is still on the tree continue with modification during storage, the period after ripening and before picking being, so to speak, storage on the tree.

The work of Lindet [3] shows that the *acid* content diminishes slowly during growth, while the *carbohydrates* increase. *Sucrose* and *invert sugar* increase throughout growth, but starch reaches its maximum when the ripening processes begin, its subsequent gradual disappearance being accompanied by an increase in sucrose. The author brings out three distinct transformations in the carbohydrates group: (1) the hydrolysis of starch with formation of sucrose, (2) the hydrolysis of sucrose with formation of invert sugar, and (3) respiration with formation of carbon dioxide from invert sugar.

Browne [4] analyzed Baldwin apples on four dates, extending from Aug. 7 to Dec. 15, covering the periods of late growth and of ripening to over-ripeness, with the results given in the following table:

[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Ind. ital. conserve aliment. 1934, **9**, 19.

[3] Ann. agron. 1894, **20**, 5.

[4] Loc. cit.

Composition of Apple Flesh at Different Stages of Growth (Browne)

	Water	Solids	Acids as malic	Sugars, total	Invert sugar	Sucrose	Starch	Ash
	%	%	%	%	%	%	%	%
Very green.....	81.53	18.47	1.14	8.03	6.40	1.63	4.14	0.27
Green..........	79.81	20.19	....	10.51	6.46	4.05	3.67	....
Ripe...........	80.36	19.64	0.65	14.51	7.70	6.81	0.17	0.27
Over-ripe......	80.30	19.70	0.48	14.07	8.81	5.26	....	0.28

Bigelow, Gore, and Howard,[1] in extensive studies on the growth and ripening of three varieties each of Summer and Winter apples, corroborate Browne's conclusions, although the changes in the case of the Summer varieties were somewhat irregular. As shown by tables and graphs, the results during the early growth indicate a marked increase in *invert sugar, sucrose, starch,* and *total solids* but a decrease in *acids.* These tendencies continued during later growth and ripening, except that starch gradually diminished, the loss being manifest in the corresponding increase in sucrose so that the sum of the starch and sucrose remained nearly unchanged through a considerable period. The results on the flesh of a single Winter variety, Ben Davis, given below illustrate in general the changes that take place:

Composition of Apple Flesh at Different Stages of Growth (Bigelow and Gore)

	Weight	Solids	Acids as malic	Sugars,* total	Sugars,* reducing	Sucrose	Starch
	gr.	%	%	%	%	%	%
June 16.......	15.4	13.63	1.64	3.87	2.35	0.49	2.23
June 30.......	32.5	13.37	1.27	3.74	3.04	0.67	3.03
July 13†......	32.1	13.58	....	6.36	5.09	1.21	0.72
July 28.......	58.6	15.71	0.89	5.71	4.52	1.13	3.67
Aug. 18.......	95.4	14.92	0.78	5.90	4.36	1.46	3.16
Sept. 24.......	130.2	15.05	0.52	7.56	4.83	2.59	2.40
Oct. 15.......	167.9	14.86	0.52	8.60	5.30	3.13	1.46
Oct. 23.......	149.5	14.82	....	9.60	5.53	3.92	0.94
Oct. 30.......	178.6	14.68	0.43	9.91	5.84	3.87	0.38
Nov. 5.......	147.4	15.73	0.41	9.74	5.83	3.71	....

* As invert sugar. † Held in icebox since preceding date.

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[1] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **94**.

Neidig, Colver, Fishburn, and Von Ende [1] employ the *refractive index* as a measure of carbohydrate changes and the *electrical conductivity* as a measure of potassium content. They corroborate earlier workers who found a rapid increase in *invert sugar* and *starch* during growth and an increase in *sucrose* at the expense of starch during ripening.

No progressive variation in *ash*, *acid*, *total* and *reducing sugars*, or *hydrogen-ion concentration* was brought out in experiments by St. John,[2] although protein tended to decrease as did also, in the later stages, substances insoluble in alcohol and hydrolyzable by acid.

The results by Archbold [3] show an increase in percentages of *total solids* and *soluble carbohydrates*, which was slow during the early stages, but was rapid after Aug. 5. *Total nitrogen* and *acidity* reached their peak on June 22 and *alcohol-insoluble residue* on July 15, both decreasing thereafter.

Haller's experiments [4] indicate that the softening of apples during both ripening and storage is to some extent associated with a change of insoluble protopectin to a soluble form, the small amount of pectin remaining constant. The amount of pectic constituents, however, does not account for differences in firmness of different varieties.

Relation of Size to Composition.—Results by Kulisch [5] point to the general rule that the larger the apple the higher the sugar content and, in most cases, the higher the acid content. He believes that acid and sugar stand in no relation to each other, in opposition to the theory that the increase of one is accompanied by the decrease of the other.

Influence of Climate on Composition.—Climatic factors are believed to be largely responsible for the variation in composition of apples of the same variety, as shown by Caldwell's analyses given in a foregoing table. That author,[6] however, refutes the optimum temperature theory, which assumes that each variety requires for its proper development a certain mean Summer temperature. Varieties of both high and low temperature groups behaved as a unit. The temperature conditions favoring high quality, as measured by composition in one group, favored also high quality in the others, and all varieties showed more adaptability to the variations in temperature than is assumed by the optimum temperature theory.

Archbold [7] emphasizes the point that high acid and low sucrose content are correlated with low temperature and lack of sunshine. Archbold and Lall[1] note marked differences in the dry weight and protein of apples of the same variety grown in different localities and conclude that environment may exert a greater influence on composition than variety.

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[1] Idaho Agr. Exp. Sta. Rep. 1917, p. 22.

[2] Washington Agr. Exp. Sta. 1924, Bul. **187**.

[3] Ann. Bot. 1928, **42**, 541.

[4] J. Agr. Res. 1929, **39**, 739.

[5] Landw. Jahrb. 1892, **21**, 427.

[6] J. Agr. Res. 1928, **36**, 367.

[7] Loc. cit.

Influence of Irrigation on Composition.—Two samples of apples (Newtowns) from irrigated trees contained, according to Bradley,[2] 16.17 and 15.23 per cent of total solids, while 2 samples from non-irrigated trees contained somewhat more, namely 18.98 and 15.67 per cent. On the dry basis, the samples contained total sugars 73.27 and 78.19 (irrigated), 63.78 and 66.99 (non-irrigated); reducing sugars 44.58 and 47.86 (irrigated), 38.87 and 40.00 (non-irrigated); sucrose 28.69 and 30.33 (irrigated), 24.91 and 26.99 (non-irrigated); acidity 3.83 and 5.25 (irrigated), 5.06 and 4.46 per cent (non-irrigated). From these results and others it appears that irrigation decreases the percentages of solids in the fruit and increases the various sugars in the solids.

Changes in Composition During Storage.—Kulisch[3] followed the changes in composition of apples stored in a cellar from early in October until early in April. During the first month the content of *reducing sugars* and *sucrose* increased and of *starch* decreased markedly, while that of acid began a gradual uninterrupted decline. The increase in content of reducing sugars and the decrease in the content of acids continued until spring, while the sucrose content, as soon as the starch supply was exhausted, dropped sharply and continued to decrease throughout the experiment.

Bigelow, Gore, and Howard[4] obtained analogous results with three Winter varieties, Rhode Island Greening, Northern Spy, and Winesap, in common storage, while in cold storage the losses and gains were of the same general nature but at a retarded rate. Results on winesap apples appear in the first table on the next page.

Neidig, Colver, Fishburn, and Von Ende[5] could not find any marked chemical differentiation between cellar and cold storage apples.

In experiments conducted by Magness and Diehl,[6] the decrease in *acidity* during storage varied somewhat with the kind of container and the wrapping, as shown (recalculated) in the second table. The respi-

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[1] Dept. Sci. Ind. Res. Rep. Food Invest. Bd. 1930, p. 161.

[2] J. Ind. Eng. Chem. 1911, **3**, 496.

[3] Landw. Jahrb. 1892, **21**, 871.

[4] Loc. cit.

[5] Loc. cit.

[6] J. Agr. Res. 1924, **27**, 1.

Composition of Apple Flesh after Storage (Bigelow et al.)

Storage	Date of anal.	Solids	Acids as malic	Sugars,* total	Sugars,* reducing	Sucrose	Starch	Pentosans	Cellu lose
		%	%	%	%	%	%	%	%
Ordinary									
	1902 Oct. 6	15.60	0.64	9.81	7.68	2.02	1.51	....	....
	Nov. 7†	16.92	0.55	11.78	8.23	3.55	0.37	0.75	1.06
	Nov. 25	16.02	0.50	12.07	9.74	2.21	0.16	0.73	0.89
	Dec. 9	17.04	0.42	13.16	11.12	1.94	0.00	....	....
Cold									
	1902 Oct. 20	17.52	0.66	11.49	8.72	2.63	1.00	....	....
	1903 Jan. 19	17.06	0.57	11.71	9.88	1.74	0.00	....	....
	May 5	17.35	0.47	11.65	10.63	1.23	0.00	....	....
	Dec. 17	16.31	0.38	10.65	9.98	0.64	0.00	....	....

* As invert. † On this date the apples contained: total nitrogen 0.033, soluble nitrogen 0.008, total ash 0.282, and alkalinity of ash calculated as potassium carbonate 0.195%.

ration increased with the temperature. At 0° C., 1.97 mg. per kilo of carbon dioxide was evolved per hour, while at 18° C. the rate was 16.45 mg. and at 26° C. was 23.7 mg., the ratio of carbon dioxide to oxygen indicating aerobic respiration.

Acid as Malic in Apples before and after Storage (Magness and Diehl)

	When Stored	After Storage at 0° C. in —			
		Barrel	Wrapped box	Wrapped box, oil paper	Unwrapped basket
	%	%	%	%	%
Rome Beauty:					
1st pick	0.41	0.30	0.31	....	....
2nd pick	0.34	0.32	0.29	0.26	....
Ben Davis:					
1st pick	0.56	0.41	....	0.49	0.52
2nd pick	0.55	0.39	0.33	0.38	0.35
Dill:					
1st pick	0.21	0.15	0.12	0.11	....
2nd pick	0.19	0.13	0.11	0.14	....
R. I. Greening:	0.62	0.52	0.57	0.56	....

Carré[1] distinguishes between *insoluble pectin* (*protopectin*), the only form present during the early ripening, and *soluble pectin* which gradually develops, reaching its maximum when the fruit is fully ripe and decreasing thereafter. Both forms decrease in over-ripe fruit. He dissolved insoluble pectin by heating in an autoclave with 0.05 normal hydrochloric acid. The progressive change in cold storage differs from that in ordinary storage merely in that it proceeds more slowly.

In a later paper Carré[2] reports results on (1) *pectin* and *pectinic acid*, both soluble in cold water, (2) *pectose* extracted by hydrolysis with 0.0125 normal sodium hydroxide, and (3) *pectin substances of the middle lamella* extracted, after the removal of the preceding forms, by 0.0125 normal hydrochloric acid. In apples stored at 1° C., the total pectin content changed little until May, when it decreased. The percentage of soluble pectin increased until March, then remained constant. The pectose content decreased until February, then increased and again decreased in April. Pectins in the middle lamella showed no change until January, when they began to decrease. Total and insoluble pectin decreased at the time malic acid decreased most rapidly, owing perhaps to the greater activity of enzymes in the weaker acid solution.

St. John[3] records an increase in *sugars* and a decrease in *alcohol-insoluble* and *hydrolyzable matter* during storage.

According to Emmett,[4] the chemical processes involved in the storage of apples and pears are similar, but *soluble pectin* continues to form in the apple at temperatures slightly above freezing, which are inhibitory for their formation in the pear. At these low temperatures, cellulose also appears to be hydrolyzed, whereas in the pear at somewhat higher temperatures only pectin substances are changed.

During storage for 6 months in moist air Rivière and Pichard[5] noted a loss in weight of 3.33 to 4.55 per cent of which only about one-tenth was carbon dioxide. The loss reached 6 per cent in a case where the fruit was infested with *Molinia fructigena*.

The conclusion was reached by Neller and Overley[6] that the varieties Delicious and Jonathan are in the best condition for storage when the rapid increase in *total sugars* ceases, thus allowing the ripening process to take place on the tree rather than during storage. The range in the increase of sucrose for the two varieties during a six weeks' period, beginning two weeks before and four weeks after the usual time of harvesting, was respectively 182 and 80 per cent.

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[1] Biochem. J. 1922, **16**, 704.

[2] Ann. Bot. 1925, **39**, 811.

[3] Loc. cit.

[4] Dept. Sci. Ind. Res. Food Invest. Bd. Rep. 1925/6, p. 47.

[5] Bul. soc. chim. 1926, **39**, 802.

[6] Washington Agr. Exp. Sta. 1926, Bul. **205**.

Plagge, Maney, and Gerhardt,[1] in experiments with Grimes apples, showed that ripening, whether on the tree or during storage, was correlated with a loss of *water*, *acid*, *dextrin*, *starch*, and *substances hydrolyzed by acid* and a gain in *specific gravity*, *sugars*, and *soluble pectin*. After holding in cold storage, the composition was practically the same, regardless of considerable difference in the degree of ripeness when picked. Plagge and Gerhardt [2] traced the changes in total (titratable) *acidity* and *H-ion concentration* of Grimes and Jonathan apples under various storage conditions. Although the total acidity declined in some cases as much as 3.5 per cent between the second and fourteenth day after picking and before storage, the greatest change in H-ion concentration was only pH 0.26. During storage further losses of total acidity took place but the tendency was toward uniformity at a given storage temperature, that is, the total time after picking rather than the time of storage appeared to be most significant. An increase in storage temperature lowered the total acidity. To prevent soggy breakdown, immediate storage or storage at a temperature high enough to permit loss of acidity " at a more favorable and rapid rate " is recommended.

Archbold [3] and Widdowson [4] give chemical data beginning after three weeks' development when the dry matter contained *alcohol-insoluble substances*, including acids, 38 per cent and *sugars* 15 per cent. The period of *starch* synthesis extended from the middle of June until the end of October, the maximum of 1.5 to 2.0 per cent being reached in mid-Summer when the alcohol-insoluble substances and acids fell to 17 per cent and the sugars rose to 55 per cent. During final ripening, hydrolysis of most of the starch was effected, the alcohol-insoluble substances and acids fell to 14 per cent, and the sugars rose to 80 per cent. During storage the remainder of the starch was hydrolyzed, the *sucrose* was inverted, and the acid and alcohol-insoluble substances slowly diminished; *dextrose*, however, remained nearly constant in amount throughout the period. Widdowson notes the presence of a polyuronide and a polysaccharide, both yielding arabinose on hydrolysis and consequently classed as hemicelluloses. These, as well as pectin, increase during ripening to the maximum amount which remained constant during storage.

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[1] Iowa Agr. Exp. Sta. 1926, Res. Bul. **91**.

[2] Ibid. 1930, Res. Bul. **131**.

[3] Ann. Bot. 1932, **46**, 407.

[4] Ibid. p. 597.

The storage life of the apple, according to Kidd, Onslow, and West,[1] varies inversely with the nitrogen and sucrose content, the sucrose being the probable substrate in the respiration, but directly with the available potash in the soil. The rate of loss of sucrose increases, its hydrolysis decreases, during storage.

Respiration.—Bigelow, Gore, and Howard [2] showed that respiration is much more rapid in the cellar than in cold storage at 0° C.

Morse [3] emphasizes the importance of a low temperature during storage, thereby diminishing the respiration. In his experiments, Summer temperature brought about four to six times as rapid an evolution of carbon dioxide as cold storage.

Gore,[4] operating with 5 varieties of apples, noted a maximum evolution of 65 mg. of carbon dioxide per kilo per hour at 34.1° C., and a minimum of 3 mg. at 2.5° C. See also Magness and Diehl above.

Water-Core.—This term is applied to a glassy appearance extending throughout the fruit or only in parts. The intercellular spaces instead of containing air are filled with the fruit juice. Commonly this condition is attributed to an excess of water in the soil.

Paris [5] employed both histological and chemical methods in his search for the cause of the disease. Analyses show an excess of water in water-core ("glassy") apples, also an excess or deficiency of other constituents as appears in the following table:

Composition of Water-Core and Normal Apples (Paris)

(Results on dry basis)

	Water, fresh basis	Protein	Acids as malic	Sugars, reducing	Sucrose	Pentosans	Cellulose	Ash
	%	%	%	%	%	%	%	%
Crop of 1909:								
Water-core...	87.20	0.63	0.85	50.33	6.84	4.02	12.62	1.59
Normal.....	83.45	0.75	0.91	53.85	11.52	6.07	8.45	1.36
Crop of 1913:								
Water-core...	86.89	0.57	0.95	49.14	11.72	4.60	11.57	1.69
Normal......	82.38	0.68	2.14	51.09	18.32	5.22	7.61	1.40

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[1] Dept. Sci. Ind. Res. Rep. Food Inspec. Bd. 1929, p. 44.

[2] Loc. cit.

[3] J. Am. Chem. Soc. 1908, **30**, 876.

[4] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[5] Staz. sper. agr. ital. 1914, **47**, 702.

Further investigation of the dry pulp showed that, in addition to an excess of cellulose (crude fiber?), there was an excess of lignin and fat, glassy apples containing 3.75 and 2.03 per cent and normal apples 2.12 and 1.11 per cent respectively. Corroboratory evidence was furnished by microscopic sections showing that the cell walls are unduly thickened and lignified. The author concluded that the abnormal condition of the walls rendered them impermeable to air. He was able to produce this condition artificially by coating the fruit with paraffin.

Brooks and Fisher [1] give a bibliography of twenty-seven titles which does not include the work of Paris, possibly because it was abstracted under the head "glass apples." [2] Because of the common belief that excessive moisture is the cause of the disease, their work was with apples grown on irrigated trees. Contrary to the accepted belief, light irrigation produced more water-core than heavy. Some of the other conditions favoring water-core were free exposure of the fruit to sunlight, large size of fruit, and over-maturity. Fertilization with potassium nitrate usually diminished the water-core, and picking at the proper stage was found to be the best preventive. They state that the present evidence points to sap exudation under pressure as the cause of the disease, rather than variation in rainfall or soil moisture.

Fatty Oil of Seed.—The values of apple seed oil, as given by N. and H.,[3] follow, the figures in parentheses being those given on the authority of other workers: refractive index at 25° C. 1.4726, saponification number 189.5 (202), iodine number 119.8 (135.0), acid number 2.9 (57), saponification number of fatty acids 195.5, iodine number of fatty acids 129.5, and unsaponifiable matter 1.2 per cent.

Wax Coating.—Seifert [4] describes two wax-like substances melting at 64 and 234° C.

By moistening apple parings with sodium hydroxide, extracting with ether, and evaporation of the solution, Thomae [5] secured a powdery odorless preparation soluble in hot alcohol which, purified, melted at over 200° C. It was further separated into high and low melting point substances, the latter being a wax crystallizing as needles melting at 68.5° C.

Sando [6] isolated three distinct substances: (1) *triacontane*, $C_{30}H_{62}$, melting at 63.5 to 64° C., believed to be the same as found by Power and Chesnut[1] in an impure form, also small amounts of other fractions melting at 70 to 79.5° C.; (2) *heptacosanol*, $C_{27}H_{56}O$, melting at 81 to 81.5° C. (acetate 44 to 46° C.); and (3) *malol* (ursolic acid), $C_{30}H_{48}O_3$, separated as lustrous prismatic needles melting at 284 to 285° C.

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[1] J. Agr. Res. 1926, **32**, 223.

[2] Chem. Abs. 1915, **9**, 1811, through Chem. Zentr. 1915, I, 493.

[3] Z. angew. Chem. 1916, **29**, I, 337.

[4] Landw. Vers.-Stat. 1895, **45**, 29.

[5] J. prakt. Chem. 1911, **84**, 247; 1913, **87**, 142.

[6] J. Biol. Chem. 1923, **56**, 457.

Van der Haar[2] proved that the malol of Sando is identical with the *prunol* of Power and Moore[3] obtained from the leaves of *Prunus serotina* and the *ursone* of Trommersdorff[4] present in the leaves of *Arctostaphylos uva-ursi.* He considered the formula to be $C_{31}H_{50}O_3$. Since the substance is acidic in its character, Sando[5] proposed a new name, *ursolic acid*, but adhered to the formula, $C_{30}H_{48}O_3$, first suggested by Gintle.[6] Markley and Sando[7] observed that the oily fraction increases faster than the ursolic acid during growth and that both were greater in mature fruit grown in New York than in that grown in Washington state.

Chibnall, Piper, Pollard, Smith, and Williams[8] identified *n-nonacosane, n-heptacosane, d-10-nonacosanol, n-octacosanol,* and *n-triacontanol.* Markley, Hendricks, and Sando[9] found that the petroleum ether extract of the cuticle consists chiefly of *nonacosane*, melting at 65.1° C., and *10-nonacosanol*, and contains no ketone.

Acids.—The belief long held, that *malic acid* is the only acid present in the apple in appreciable amount, appears to be well grounded. The conclusion of Chauvin, Joulin, and Canu,[10] that the acid is citric, lacks support. Bigelow and Dunbar[11] give results of determinations of total acids, calculated as citric, and of malic acid by the uranyl acetate method, obtained by five analysts in the Bureau of Chemistry, which show close agreement, and they conclude that malic is the only acid of the apple. Muttelet[12] found 0.13 to 0.75 per cent of actual malic acid in several types of apples and no other fixed acid. Franzen and Helwert[13] report considerable *citric acid* in apples. Nelson,[14] by the ester distillation method, found in Winesap apples *l*-malic acid together with traces of citric, but in York Imperial he found no citric acid.

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[1] J. Am. Chem. Soc. 1920, **42**, 1509.

[2] Rec. trav. chim. 1924, **43**, 367.

[3] Pharm. J. 1910, **84**, 710; J. Chem. Soc., 1910, **97**, 1099.

[4] Arch. Pharm. 1854, **130**, 273.

[5] J. Biol. Chem. 1931, **90**, 477.

[6] Monatsch. 1893, **14**, 225.

[7] J. Agr. Res. 1931, **42**, 705; 1933, **46**, 403.

[8] Biochem. J. 1931, **25**, 2095.

[9] J. Biol. Chem. 1932, **98**, 103.

[10] Mon. sci. 1908, **69**, 449.

[11] J. Ind. Eng. Chem. 1917, **9**, 762.

[12] Ann. fals. 1922, **15**, 453.

[13] Z. physiol. Chem. 1923, **127**, 14.

[14] J. Am. Chem. Soc. 1927, **49**, 1300.

Carbohydrates.—The predominence of *levulose* over *dextrose* in apple juice was brought out by Thompson and Whittier[1] and confirmed by Worcollier[2] and Eoff.[3] The table below gives the proportion of the sugars in 7 of the 20 juices analyzed by Eoff, the selection being made to show the extremes in composition.

Variety	In Juice			In Total Sugars		
	Dextrose	Levulose	Sucrose	Dextrose	Levulose	Sucrose
	%	%	%	%	%	%
Grimes	0.5	5.8	3.6	5.0	58.6	36.4
Limbertwig	3.5	5.0	0.8	37.6	53.8	8.6
Gano	3.2	5.9	1.3	30.8	56.7	12.5
Beck	3.3	6.3	2.4	27.5	52.5	20.0
Plumb Cider	1.4	5.9	0.6	17.7	74.7	7.6
Bonne-de Frieulles	2.7	8.5	2.6	19.6	61.6	18.8
Amère-du-Surville	2.3	7.2	0.2	23.7	74.2	2.1

Evans[4] states that the amount of levulose is two to three times that of dextrose in apples when picked. Stored at 1° C. levulose decreases slightly and dextrose increases slightly.

Warcollier[5] states that 8 to 30 per cent of the total sugars is *sucrose* and that fermentation is not retarded by the larger amount, indicating that inversion takes place well ahead of alcohol formation.

Experiments by Neller and Overley[6] show that, beginning 2 weeks before the usual harvest date and ending 4 weeks after, the sucrose content of Delicious and Jonathan apples increased 182 and 80 per cent respectively, accompanied by a decrease of the starch content of Delicious and of the acid content of Jonathan. They recommend harvesting when the ripening process has spent its force, as indicated by the slowing up of the increase of total sugars.

Pectins.—See introduction to this volume. The pectin substance present in apple juice suffices to make a stiff jelly. A rich store also remains in the cell walls of the pomace from which it now is extracted on a commercial scale and used in aiding the gelatinization of other fruit juices. By means of such preparations, jellies may be made with little concentration thereby avoiding loss of volatile flavoring constituents.

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[1] Delaware Agr. Exp. Sta. 1913, Bul. **102**.

[2] Ann. fals. 1909, **2**, 425.

[3] J. Ind. Eng. Chem. 1917, **9**, 587.

[4] Ann. Bot. 1928, **42**, 1.

[5] Compt. rend. 1907, **144**, 987.

[6] Washington Agr. Exp. Sta. 1926, Bul. **205**.

The work of Carré is reviewed under Microscopic Structure and Changes in Composition During Storage; that of Haller under Changes in Composition During Growth and Ripening.

Kertesz and Green[1] have shown that apple pomace containing 20 per cent or less of water may be stored 5 months without serious loss of pectin and substances yielding pectin on hydrolysis, but if the pomace contains 33 to 50 per cent of moisture the growth of molds and consequent loss of pectin substances take place.

Amygdalin.—Huber[2] reports in the dry seeds 0.62 to 1.38 per cent of amygdalin equivalent to 0.037 to 0.082 per cent of hydrocyanic acid.

Colors.—The yellow color of the McIntosh apple has been shown by Sando[3] to consist of *quercetin* (tetrahydroxyflavonol), $C_{15}H_{10}O_7 + 2H_2O$, which had previously been found in the bark of young apple twigs. He suggests that this substance or its glucoside may be the chromogenic substance causing the formation of a brown color on scalding. Potter[4] was unable to find any difference in vitamin A potency between apples with white and those with yellow flesh.

Experiments by Fletcher[5] indicate that the red color of apples is not influenced by inorganic fertilizers and chemicals and is little affected by nitrogenous fertilizers. Sugar added to the soil intensified the color and also increased the sugar content, whereas inclosing the fruit in red cellophane bags inhibited its formation.

Odorous Constituents.—By distillation with steam, Thomae[6] secured a watery liquid with oil drops on the surface having an agreeable odor. The extract obtained by shaking with ether, on evaporation, yielded a soft mass from which a network of crystals separated on treatment with alcohol. On filtering and evaporation of the solvent a yellow odorous oil was obtained. In later experiments,[7] he prepared liquid extracts of an odorous nature, but no serious attempt appears to have been made to isolate the constituent ethers.

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[1] New York Agr. Exp. Sta. 1931, Tech. Bul. **179**, 3.

[2] Landw. Vers.-Stat. 1911, **75**, 462.

[3] J. Agr. Res. 1924, **28**, 1243.

[4] J. Nutrition 1933, **6**, 99.

[5] Maryland Agr. Exp. Sta. 1933, Bul. **353**, 79.

[6] Loc. cit.

[7] J. prakt. Chem. 1913, **87**, 142.

Power and Chesnut[1] identified as the chief odorous constituents the *amyl esters of formic, acetic,* and *caproic (hexoic) acids* with a very small amount of *caprylic ester* and a notable amount of *acetaldehyde.* The acids appear to be present to some extent in the free state. Acetaldehyde was shown to be formed by the vital processes and not during steam distillation and is exhaled to some extent at maturity. In addition to the substances named, minute quantities of *methyl* and *ethyl alcohols* and a small amount of furfural occur in the distillate from apple parings, but the furfural is doubtless formed during distillation. By ether extraction, an essential oil of high apple fragrance was obtained and from this on standing small acicular crystals consisting of a paraffin hydrocarbon separate. The yield of essential oil from Ben Davis and crab apples was 0.0035 and 0.0043 per cent in the parings equivalent to 0.0007 and 0.0013 per cent in the entire fruit. Amyl valerate, although known as "apple oil," has never been identified as a constituent of apples. Acetaldehyde had previously been found in apples by Müller-Thurgau and Osterwalder,[2] but in much smaller amounts than in pears.

Kodama[3] describes, as flavoring constituents of the apple, certain esters, prepared from by-products formed during the decomposition of proteins, such as ethyl-α-acetoxy-iso-hexoate, the corresponding methyl ester, ethyl-α-benzoyloxy-iso-hexoate, ethyl-α-isovaleryl-iso-hexoate, etc., which Power and Chesnut[4] claim are not present.

From McIntosh apples, a particularly fragrant variety, Power and Chesnut[5] isolated the aliphatic terpene alcohol *geraniol* ($C_{10}H_{18}O$).

According to Thomas[6] neither *acetaldehyde* nor *alcohol* accumulates in healthy apples and pears but may occur in fruit injured by too low temperature of storage or deep scald.

Enzymes.—Thatcher[7] concludes that *oxidases* are the only enzymes that produce changes in the carbohydrates during ripening. *Esterase* and *protease,* present in small amounts, appear to be formed by hydrolytic changes in the essential oil and protein.

Neidig, Colver, Fishburn, and Von Ende[8] found no conclusive evidence of the presence of *diastase* or *invertase* but were able to establish the presence of *esterase* and, in green apples, *oxidase.*

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[1] Loc. cit.

[2] Landw. Jahrb. Schweiz. 1915, p. 400.

[3] J. Tokyo Chem. Soc. 1920, **41**, 965.

[4] J. Am. Chem. Soc. 1921, **43**, 1741.

[5] Ibid. 1922, **44**, 2938.

[6] Ann. Appl. Biol. 1931, **18**, 60.

[7] J. Agr. Res. 1915, **5**, 103.

[8] Idaho Agr. Exp. Sta. 1918, Bul. **104**.

Studies by Overholser and Cruess[1] indicate that *peroxidase*, an *organic peroxide*, and a chromogen, *tannin*, belonging to the catechol group, are responsible for the darkening of apple tissues. Boiling and precipitation of the peroxidase and peroxide prevent the reaction, but it again takes place on addition of some of the precipitate to the solution in which the tannin is still present. The organic peroxide was rendered inactive at 73.5 to 78° C., the peroxidase at 90 to 100° C. Immersion in 5 per cent hydrochloric acid and sodium sulphite for 3 days, as well as treatment with sulphurous acid, appeared to destroy the organic peroxide, whereas sodium chloride merely inhibited the reaction. Various other solutions favored darkening. Treatment with salt solution (3 to 5 per cent) was a satisfactory substitute for sulphuring dried apples, although the product was slightly darker.

Balls and Hale[2] consider that the formation of *hydrogen peroxide* by a respiratory enzyme is a necessary preliminary step and that darkening continues until this is completely utilized by the peroxidase. They propose, as a preventative of discoloration during drying, treatment of sliced apples with a dilute solution of glutathione or cysteine salts or else pineapple juice.

Carrick[3] showed that the *catalase* activity of the vascular system was greater than that of the parenchyma. McIntosh apples, kept at 7.5° C. for 3 to 9 hours, showed an increase in catalase when tested immediately and in some cases four days after, but kept at that temperature for 20 hours the catalase was nearly destroyed. Baldwin apples gave somewhat different results.

Mineral Constituents.—Results on the whole fruit as given by Wolff,[4] by Haskins,[5] and by Colby,[6] follow:

	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO
	%	%	%	%	%	%	%	%
Wolff	0.22	0.08	0.06	0.01	0.02	0.03	0.01	0.01
Haskins	0.41	0.19	0.03	0.03	0.03	0.01	....	....
Colby	0.26	0.14	....	0.01	....	0.03	....	....

The higher percentage of total ash, as given by Haskins, appears to be due to carbon dioxide, which, in the analysis given by Wolff, was doubtless deducted. Browne,[1] who considers 0.30 per cent as a fair average for total ash in the fresh fruit, gives the following analysis:

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[1] California Agr. Exp. Sta. 1923, Tech. Paper No. 7.

[2] Ind. Eng. Chem. 1935, **27**, 335.

[3] Cornell Agr. Exp. Sta. Mem. 1929, **122**.

[4] Aschenanalysen.

[5] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[6] California Agr. Exp. Sta. Rep. 1898, p. 143.

K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	P_2O_5	SO_3	SiO_2	Cl	CO_2
%	%	%	%	%	%	%	%	%	%	%
55.94	0.31	4.43	3.78	0.95	0.80	8.64	2.66	0.40	0.39	21.60

Brown [2] found that in apples grown in England there is a relationship between the amount of potash in the soil and in the fruit and a probable relationship in the case of phosphoric acid, lime, and magnesia. Good keeping qualities were associated with high content of potash and phosphoric acid. The mechanical condition of the soil also is a factor in mineral uptake.

Among the points brought out by Hopkins and Gourley [3] are the increase in the percentage of ash and of the potassium in the ash, also the decrease in calcium and phosphorus in the ash, resulting from potassium in the fertilizer.

Studies by DeLong [4] on Wagener apples grown in Nova Scotia brought out that (1) application of potassium increased greatly the potassium in the fruit, (2) the influence of phosphorus as acid phosphate and basic slag on the content of that element was slight, and (3) sodium nitrate diminished the ash content.

Minor Mineral Constituents. *Iron.*—Edible portion 3 mg. per kilo, fresh basis (Sherman).[5] Edible portion 3 mg. per kilo (Bunge, quoted by Sherman).[5] Edible portion: Greening 6.1, Snow 5.8 mg. per kilo, fresh basis (Peterson and Elvehjem).[6] Fruit, 2 samples, 2.6, 3.1 mg. per kilo, fresh basis (Toscani and Reznikoff).[7]

Aluminum.—Edible portion 0.47 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[8] Fruit 12.7 mg. per kilo, dry basis (Bertrand and Lévy).[9]

Copper.—Fruit 1.2 mg. per kilo, fresh basis, 7.4 mg. per kilo, dry basis (Guérithault).[10] Edible portion: Greening 0.8, Snow 1.2 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[11]

[1] Pennsylvania Dept. Agr. 1899, Bul. **58**.

[2] Ann. Bot. 1929, **43**, 817.

[3] Ohio Agr. Exp. Sta. 1933, Bul. **519**.

[4] Sci. Agr. 1933, **13**, 505.

[5] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[6] J. Biol. Chem. 1928, **78**, 215.

[7] J. Nutrition 1934, **7**, 79.

[8] Am. J. Physiol. 1929, **90**, 72.

[9] Bul. soc. hyg. aliment. 1931, **19**, 359.

[10] Compt. rend. 1920, **171**, 196.

[11] J. Biol. Chem. 1929, **82**, 465.

Zinc.—Edible portion: unknown variety 1.6, Russet 0.4 mg. per kilo, fresh basis (Bertrand and Benzon).[1]

Arsenic.—Fruit 0.05 mg. per kilo, fresh basis (Jadin and Astruc).[2]

Iodine.—Fruit none (Winterstein).[3]

CRAB APPLE

Pyrus baccata L. = *Malus baccata* Borkh.
= *M. microcarpa* var. *baccata* Carr.

Fr. Pomme sauvage. It. Pomo salvatico. Ger. Holzapfel.

This species from northern Asia, known as the Siberian crab, has furnished most of our cultivated varieties. Two native American species, the eastern crab (*P. coronaria* L. = *M. fragrans* Rehd.) and the western crab (*P. ioensis* Bailey = *M. ioensis* Brit.), although introduced into cultivation as ornamentals, have edible fruits of some value. The Soulard crab (*P. Soulardii* Bailey = *M. Soulardii* Brit.), believed to be a natural hybrid of *P. ioensis* and *P. Malus*, yields an edible fruit of considerable size.

MACROSCOPIC STRUCTURE.—The *calyx* of the Siberian crab is deciduous, that of the two American species is persistent; in the western crab it is glabrous and in the eastern crab pubescent.

MICROSCOPIC STRUCTURE.—The *epiderm* of the fruit has smaller and thinner-walled cells than that of the apple. The maximum longitudinal diameter in samples examined reached only 40 μ. In other respects the structure of the pericarp and the seed did not differ noticeably from that of the common apple.

PEAR

Pyrus communis L.

Fr. Poire. Sp. Pera. It. Pera. Ger. Birne.

Most of the varieties of pears grown in Europe and America are derived from the common species (*P. communis*), a native of temperate Europe and western Asia; some, however, notably the Kieffer and LeConte, are hybrids of this with the Japanese or Chinese sand pear (*P. serotina* var. *culta* Rehd.). The European snow pear (*P. nivalis* Jacq.) grows wild and cultivated in France and Austria but the fruit being small and sour is used chiefly for making pear cider or perry.

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[1] Bul. soc. hyg. aliment. 1928, **16**, 457.

[2] Compt. rend. 1912, **155**, 291.

[3] Z. physiol. Chem. 1918, **104**, 54.

As a dessert fruit the pear is eaten mostly in the late Summer and Autumn, although the American markets are now supplied with California fruit throughout the Winter. Unlike most fruits, the pear develops its finest flavor if picked while still hard and ripened in the dark. Large quantities are canned and dried. The hard fruit of inferior varieties is rendered edible, but not delicious, only by cooking. Such fruit has been used in cheap European jams or dried as a coffee substitute.

MACROSCOPIC STRUCTURE.—In general characters the pear is like the apple; the *flower*, however, is white and the *fruit* commonly more or less obovate, often with a depression (with hairs) at the calyx end but less often with one at the stem end. There are, however, varieties approaching the apple in shape while the Kieffer pear tapers toward both ends, each with a shallow depression. The hairy calyx is persistent. As pears are eaten when softer than apples, the stem is readily pulled out of the tissues, the bundles separating from one another at the end appearing like the bristles of a brush. As regards the skin, the range as in the apple is from smooth and lustrous to dull or even rough, characteristic of russet fruit. The common colors are yellow and brown, often with red cheeks, but the bright red of the apple is unusual.

MICROSCOPIC STRUCTURE.—Early writers noted the stone cells of the fruit flesh, and Weiss[1] pictures them with surrounding starch parenchyma. Malfatti's studies[2] included the pear as well as the apple.

Stem.—Structure as in the apple.

Calyx.—Hairs as on fruit.

Fruit (Fig. 201).—The number of layers and some of the characters of each are the same as in the apple; there are, however, marked differences.

The *epiderm* (*epi*) exhibits in surface view the thick walls of the mother cells and thin walls of the daughter cells, but the cells are only approximately half as large as in the apple, the longer diameter reaching 35 μ. The cuticle is thick. Lenticel-like spots are numerous, often displacing the stomata and surrounding cells during the earlier stages and in russet pears covering nearly the whole surface. *Hairs* occur in the calyx depression. They have thick walls and narrow lumen thus distinguishing them from the thin-walled hairs of the apple. They are also more nearly straight, although at the tip they are often decidedly kinky.

Cross sections show a *hypoderm* of several tiers of cells which, in surface view (*hy*), are polygonal with knotty thickened walls and prominent angles. Chlorophyl grains always occur in both epiderm and hypoderm when green and in some varieties when ripe. In other varieties coloring matter in solution occurs at maturity.

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[1] Anat. Pflanzen., 1878, p. 248.

[2] Z. Nahr. Unters. Hyg. Waarenk. 1896, **10**, 265.

The *stone cells* (st^1) are isodiametric or somewhat elongated and have thick, colorless walls with marked branching canals. They occur in groups about which are elongated parenchyma cells (p^1) forming rosettes, the complexes being so numerous as to make up a large part of the fruit flesh tissue. *Calcium oxalate* occurs in small cells, most abundant in the inner mesocarp, mostly as monoclinic crystals (*cr*) often united as twins, triplets, or other small aggregates. Crystal rosettes, such as predominate in the apple, are less numerous. *Starch grains* persist in the tissues until the fruit is fully formed, but disappear when the edible stage is reached. The individual grains are smaller than those of the apple, seldom exceeding 5 μ. The elements of the *fibro-vascular bundles* and the accompanying *bast fibers* (*f*) are like those of the apple.

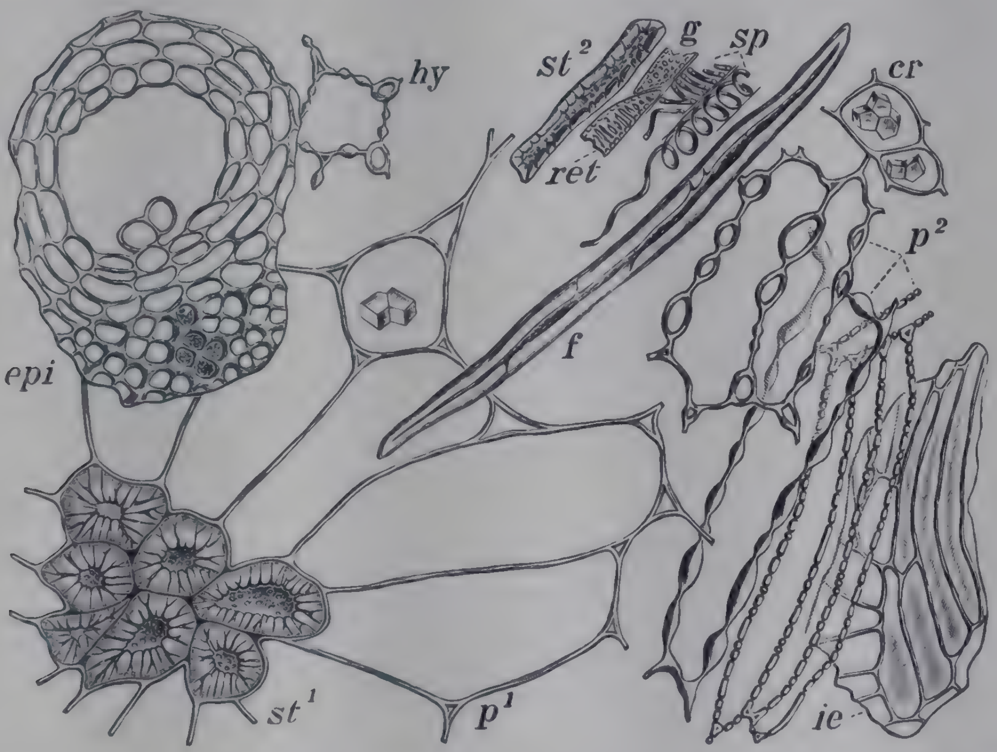

Fig. 201.—European Pear. Elements of fruit in surface view. *epi* epiderm; *hy* hypoderm; st^1 stone cell group with p^1 radiating parenchyma; *f* bast fiber, *sp* spiral, *ret* reticulated, and *g* pitted vessels, and st^2 sclerenchyma cell of fibro-vascular bundle; *cr* crystal cells; p^2 parenchyma; *ie* crossing cells of endocarp. × 160. (K.B.W.)

The parenchyma of the *inner fruit flesh* (p^2) consists of elongated cells with numerous rounded intercellular spaces forming a spongy parenchyma.

The *endocarp cells* (*ie*), although elongated as in the apple, are not strongly thickened. In the outer layers the walls have large beads, that is they are thickened and have few pores, further inward the walls are thinner with numerous pores, and finally in the innermost layer the walls are neither thickened nor porous.

A comparison of the warty *suture hairs* of the apple and pear is given under the apple. While usually sclerenchymatized members are absent in the jointed hairs of the pear, they may (as in the Glout Morceau) be numerous. The warts are less conspicuous than in the apple. In addition to the thin-walled, unicellular hairs are many thick-walled forms such as occur in the calyx depression.

Spermoderm (Figs. 202 and 203).—The *outer epiderm* (*ep*) is very different from that of the apple: first, as seen in cross section, the cells are radially elongated with a narrow, elongated or pear-shaped lumen; second, as seen in surface view, they are isodiametric and non-porous.

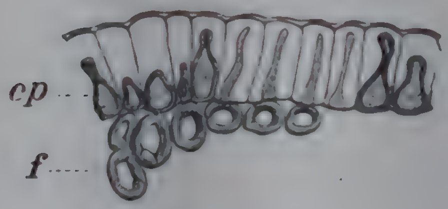

FIG. 202.

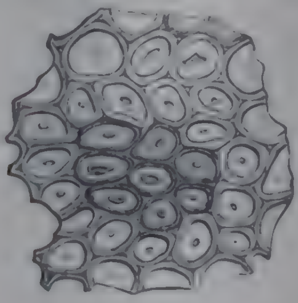

FIG. 203.

FIG. 202.—European Pear. Outer layers of spermoderm in cross section. *ep* outer epiderm; *f* fibers. × 160. (K.B.W.)

FIG. 203.—European Pear. Outer epiderm of spermoderm in surface view. × 160. (K.B.W.)

In addition to secondary mucilaginous thickenings, such as occur in the apple, groups of cells (dark in the cuts) have tertiary sclerenchymatous thickenings.

The *subepidermal fibers* (*f*) sometimes form a thicker layer than in the apple and the next layer does not have well-formed tube cells, the tissue being merely spongy parenchyma.

Perisperm, Endosperm, and **Embryo.**—As in the apple.

CHIEF STRUCTURAL CHARACTERS.—Fruit usually narrower at stem end with little or no depression; surface smooth or rough and corky; fruit flesh with stone cells groups; endocarp less woody than in apple. Seeds much as in apple.

Epidermal cells half as large as in apple; hairs thick-walled; fruit flesh of parenchyma, radiating from stone cell groups; single crystals in small aggregates more numerous than rosettes; endocarp fibers not strongly thickened; suture hairs partly smooth, thick- or thin-walled, partly warty, jointed, with or without thick-walled members. Outer epidermal cells of spermoderm radially elongated with mucilaginous thickenings and some also with sclerenchymatous thickenings.

CHEMICAL COMPOSITION.—A single analysis of green pears, made at the U. S. Department of Agriculture,[1] shows, on the fresh and dry basis, respectively: water 83.92 and none, protein 0.56 and 3.4, fat 0.79 and 5.0, nitrogen-free extract 11.46 and 70.8, fiber 2.73 and 17.5, and ash 0.54 and 3.3 per cent. The high fiber content, two to three times that of green apples, as given in the same report, is due to the stone cell concretions of the fruit flesh. Similar concretions occur in the quince and medlar but not in the apple.

The range of acids and sugars, as determined by Kremla [2] in pears of different varieties and ripeness, and of water, water-soluble matter, acids, invert sugar, sucrose, tannin, and ash, as determined by Mach and Portele [3] in different varieties, is shown below. The green samples contained less sugar but more acid than the ripe.

Composition of Pears

	Samples	Water	Solids	Acids	Invert sugar	Sucrose	Tannin	Ash
		%	%	%	%	%	%	%
Kremla:	9							
Min.		.....	....	0.04	6.56	0.00	....	....
Max.		.....	....	0.26	12.37	5.76	....	....
M. and P.:	17							
Min.		79.93	1.39	0.06	5.80	....	0.01	0.14
Max.		87.54	3.87	0.56	9.15	....	0.10	0.37

Analyses by Hotter [4] of the flesh of 18 samples of Austrian pears show the following range: total solids 14.1 to 26.6, insoluble solids 1.9 to 9.1, extract 12.6 to 17.8, total sugars as invert 7.2 to 12.7, dextrose 0.9 to 3.7, levulose 5.8 to 9.3, sucrose 0.4 to 2.6, acids as malic 0.06 to 0.6, tannin 0.02 to 0.05, total ash 0.25 to 0.59, and phosphoric acid 0.03 to 0.07 per cent.

Somewhat different constituents were determined by Olig [5] in the flesh of 2 samples of pears, as shown by the following averages: water-soluble matter 9.70, water-insoluble matter 2.66, acids as malic 0.96, reducing sugars 6.26, total ash 0.25, soluble ash 0.23, alkalinity of ash

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[1] Rep. 1881–82, p. 555.

[2] Z. Nahr.-Unters. Hyg. Waarenk. 1892, **6**, 483.

[3] Landw. Vers.-Stat. 1892, **41**, 233.

[4] Z. landw. Versuchsw. 1906, **9**, 747.

[5] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

(cc. normal acid per 100 grams of fruit) 2.67, total phosphoric acid 0.022, and soluble phosphoric acid 0.019 per cent.

Composition of Pear Juice.—Windisch and Schmidt[1] obtained, in grams per 100 cc. of juice, the results summarized below:

	Sp. gr. 15° C.	Solids	Protein	Ash, as malic	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Min...	1.047	12.22	0.24	0.63	7.07	1.47	0.16	0.34	32
Max...	1.055	14.35	0.31	0.93	8.36	2.42	0.25	0.36	34
Aver...	**1.052**	**13.45**	**0.28**	**0.75**	**7.82**	**1.95**	**0.17**	**0.35**	**33**

* Cc. *N*/10 acid per 100 cc. juice.

Composition of Pear Seeds.—The varieties Theiler and Reinholz, as analyzed by Huber,[2] contained the figures given below in percentages of the dry matter. The air-dry material contained respectively: dry kernels 58.84 and 64.36, dry hulls 36.53 and 28.46, and dry whole seeds 92.37 and 92.82 per cent.

Variety	Protein	Protein, pure*	Amygdalin	Fat†	Lecithin‡	Sugars§	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Theiler:									
Kernel.	48.56	40.03	trace	36.46	1.51	4.51	3.07	2.01	4.70
Hulls...	10.25	8.48	trace	7.13	0.82	6.08	11.97	24.47	2.50
Whole..	33.38	27.53	trace	24.84	1.23	5.13	6.72	10.90	3.83
Reinholz:									
Kernel.	51.81	43.26	trace	33.14	1.04	5.49	3.37	2.14	5.04
Hulls...	11.44	9.41	trace	7.10	0.66	5.89	14.28	18.48	2.31
Whole..	39.44	32.87	trace	25.15	0.82	5.62	6.72	7.15	4.19

* Factor 5.55. † Lecithin-free. ‡ Factor 26. § As invert.

Composition of Dried Pears.—A single analysis reported by Atwater and Bryant[3] shows as follows: water 16.5, protein 2.8, fat 5.4, nitrogen-free extract 72.9 and ash 2.4 per cent.

Changes in Composition During Growth, Ripening, and Storage.—Kelhofer,[4] Ritter,[5] and Rivière and Bailhache[6] agree that sugars increase in percentage and acidity decreases during growth. A very decided loss of tannin was also noted by Kelhofer. Although Cruess and Stone[1] noted a slight increase in soluble solids, as indicated by the Balling test, they secured varying results on acidity and no decisive evidence of a decrease in starch content.

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[1] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[2] Landw. Vers.-Stat. 1911, **75**, 443.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[4] Deut. Schweiz. Vers. Sta. Wädensweil Jahresb. 1895/97, p. 68.

[5] Deut. Obstbauztg. 1910, p. 429.

[6] J. soc. nat. hort, France, 1908, **9**, 284.

Magness[2] gives an extended digest of the literature and his own results in experiments with Bartlett pears in two regions of California (Sacramento Valley and Suisun) and one each of Oregon (Rogue River Valley) and Washington state (Yakima Valley). The samples were of three to six pickings, extending from June 10 to August 28. Analyses of the flesh, freed from skin and core, were made when picked and after storage 45 to 105 days at approximately 21°, 5°, and –1° C. In the table on the next page appear results of two pickings from two regions, omitting those of fruit stored at 5° C. which showed little difference from those at $-1°$ C. While in all cases the sugars and dry weight increased and the alcohol-insoluble, acid-hydrolyzable substances ("starch, etc.") decreased with the advance of the season, the acids decreased in the California fruit and increased in the Oregon and Washington fruit.

After storage of 6 varieties for 7 months at 1 to 2° C. in air containing 1 per cent of carbon dioxide and having a relative humidity of 70 to 80 per cent, Bottini[3] found that the table qualities were improved. No marked changes in composition, other than the destruction of sucrose, was noted after the storage. When the ripening was carried too far, carbohydrates and proteins broke down with formation of alcohols and amino acids. Scald brought about fermentation but no change in proteins.

Results by Kojima[4] show an increase in reducing sugars up to the middle of August, then a rapid decrease with a marked increase in sucrose. Starch was present only in the first period. Pectin gradually changed into a soluble modification. Perfusion, a procedure recommended in dry regions, delays sucrose formation.

Respiration.—Gore,[5] operating with 2 varieties of pears, noted a maximum evolution of 50 mg. of carbon dioxide per kilo per hour at 34.4° C. and a minimum of 3 mg. at 0.9° C.

Influence of Size of Fruit on Composition.—Kulisch,[6] in comparisons

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[1] Mo. Bul. California State Com. Hort. 1916, **5**, 425.

[2] J. Agr. Res. 1920, **19**, 473.

[3] Ann. chim. appl. 1927, **17**, 457.

[4] J. Agr. Chem. Soc. Japan 1933, **9**, 498, 504.

[5] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[6] Landw. Jahrb. 1892, **21**, 427.

Composition of Pear Flesh, Picked Green, before and after Storage (Magness)

	Solids	Acids as malic	Sugars, total	Sugars, reducing	Starch, etc.
	%	%	%	%	%
California:					
Picked July 5					
When picked......	16.03	0.36	6.00	5.40	3.77
Stored at 21° C....	15.72	0.39	8.37	7.43	1.67
Stored at −1° C...	16.07	0.26	7.77	6.50	1.56
Picked Aug. 13......					
When picked......	17.37	0.26	8.35	7.12	2.36
Stored at 21° C....	15.98	0.26	10.10	7.64	1.20
Stored at −1° C...	17.18	0.24	9.72	7.56	1.33
Oregon:					
Picked July 19......					
When picked......	15.50	0.32	6.07	5.59	3.20
Stored at 21° C....	15.64	0.39	8.19	7.39	1.55
Stored at −1° C...	15.91	0.28	7.60	6.60	....
Picked Aug. 28					
When picked......	17.28	0.36	....	....	....
Stored at 21° C....	17.70	0.36	10.10	7.95	1.35
Stored at −1° C...	17.95	0.36	10.00	7.98	1.43

made with 2 varieties, noted that the larger fruit and greater content of sugars and acids were associated with the smaller weight of the total crop.

Fatty Oil of Seed.—The values of pear seed oil, as given by N. and H.,[1] follow, the figures in parentheses being those given on the authority of other workers: refractive index at 25° C. 1.4727, saponification number 197.5 (213.0), iodine number 126.5 (121.0), acid number 2.3 (38.5), saponification number of fatty acids 203.0, iodine number of fatty acids 128.9, and unsaponifiable matter 0.5 per cent.

Wax Coating.—A paper by Markley, Sterling, Hendricks, and Sando, entitled "Constituents of the Waxlike Coating of the Pear, *Pirus Communis* L.", was read at the New York Meeting of the American Chemical Society, April 22, 1935.

Acids.—Examination of 49 samples, representing 24 varieties, by Bigelow and Dunbar,[2] showed that 37 contained only *malic acid* (0.03 to 0.46 per cent) and 2 only *citric acid* (Idaho 0.20 and Bartlett 0.25

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[1] Z. angew. Chem. 1916, **29**, I, 337.

[2] J. Ind. Eng. Chem. 1917, **9**, 762.

per cent). The remaining 10 samples contained both acids; these include 6 of Kieffer with 0.37 to 0.55 per cent of total acids, which in some cases was largely malic, in others largely citric, 3 of Bartlett with citric in all cases in excess of malic acid, and one of LeConte with 0.09 per cent of malic and 0.18 per cent of citric acid. No explanation was offered for the presence of 0.46 per cent of malic, but no citric, acid in one sample of Bartlett pears and 0.25 per cent of citric but no malic acid in another sample.

Nelson,[1] by the ester-distillation method involving the isolation of the hydrazones and the determination of melting point and specific rotation, showed that the acids of a sample of Bartlett pears consisted of two parts of citric and one part of malic acid. The presence of citric acid in the pear, previously reported by Chaubin, Joulin, and Canu,[2] is thus abundantly confirmed, but the failure of these authors to find any malic acid lacks support.

Carbohydrates.—Thompson and Whittier's theories as to carbohydrate formation appear under Apple.

Stone Cell Concretions of the pear, according to Seillière,[3] consist chiefly of pentosans yielding xylose and arabinose on hydrolysis. They contain little lime.

Acetaldehyde, as shown by Müller-Thurgau and Osterwalder,[4] which exists only in traces in apples, is formed in considerable amount in pears, especially when "sleepy." In the juice, they found by direct test and in the distillate respectively: immature 4 and 1, tree-ripe 18 to 52 and 2 to 17, storage-ripe 54 to 60 and 28 to 30, and sleepy pears 110 to 323 and 86 to 202 mg. per liter.

According to Harley,[5] acetaldehyde, which is absent in Bartlett pears while on the tree regardless of maturity, appears after two days in the ripening room at 22 to 24° C. and reaches a maximum when the core breaks down. The accumulation is greatest in late-picked fruit in which also the intercellular carbon dioxide accumulates most rapidly.

Enzymes.—A study of *catalase* activity, made by Overholser,[6] showed that the evolution of oxygen was nearly in direct proportion to the amount of hydrogen peroxide used. The maximum activity was in a slightly acid solution. Storage at −12° and 40° C. brought about at first an increase, then a decrease of the activity, and at 0 and 30° C. a gradual increase throughout a period of 22 days.

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[1] J. Am. Chem. Soc. 1927, **49**, 1300.

[2] Mon. sci. 1908, **69**, 449.

[3] Comp. rend. soc. biol. 1909, **66**, 346.

[4] Landw. Jahrb. Schweiz. 1915, p. 400.

[5] J. Agr. Res. 1929, **39**, 483.

[6] Am. J. Bot. 1928, **15**, 285.

Mineral Constituents.—Results on the whole fruit, as given b Wolff,[1] also an analysis by Colby [2] follow:

	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2
	%	%	%	%	%	%	%	%
Wolff.	3.5	1.8	0.3	0.3	0.2	0.5	0.2	0.1
Colby.	2.50	1.34	...	0.19	...	0.34	...	...

Minor Mineral Constituents. *Iron.*—Edible portion 3 mg. per kilo, fresh basi (Bunge).[3] Edible portion 4.6 mg. per kilo, fresh basis (Peterson and Elvehjem). Fruit, 2 samples, 2.4, 3.7 mg. per kilo, fresh basis (Toscani and Reznikoff).[5]

Copper.—Fruit 2.2 mg. per kilo fresh basis, 12.9 mg. per kilo, dry basis (Guéri thault).[6] Edible portion 1.0 mg. per kilo fresh basis (Lindow, Elvehjem, an Peterson).[7]

Zinc.—Edible portion 1.6 mg. per kilo, fresh basis (Bertrand and Benzon).

Arsenic.—Fruit 0.17 mg. per kilo, fresh basis (Jadin and Astruc).[9]

Iodine.—None (Winterstein).[10]

QUINCE

Cydonia oblonga Mill. = *C. vulgaris* Pers. = *Pyrus Cydonia* L.

Fr. Coing. Sp. Membrillero. It. Mela cotogna. Ger. Quitte.

In Persia, the home of the quince, its merits are appreciated as nowhere else, the fruit grown there being of such high quality as to be eaten out of hand while with us it is edible only when cooked.

The three marked pomological types regarded by Miller as species but reduced by Rehder [11] to varieties are: the pear quince (var. *pyriformis* Rehd. = *C. oblonga* Mill.), pear-shaped, the apple quince (var. *maliformis* Schneider = *C. maliformis* Mill.), apple-shaped, and the Portuguese quince (var. *lusitanica* Schneider = *C. lusitanica* Mill.), pear-shaped, large, ribbed.

[1] Aschenanalysen.

[2] California Agr. Exp. Sta. Rep. 1898, p. 143.

[3] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Nutrition 1934, **7**, 79.

[6] Compt. rend. 1920, **171**, 196.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

[9] Comp. rend. 1912, **155**, 291.

[10] Z. physiol. Chem. 1918, **104**, 54.

[11] Bailey: Stand. Cycl. Hort., New York, 1922.

Quinces are seldom seen in the market except during a short season when local fruit is placed on sale. The fruit is then baked, canned, preserved, or made into jelly, the last named being of special excellence. In the home garden, quince trees are valued because of the attractive flowers as well as the golden fragrant fruits. A few quinces will exhale fragrance in a room for weeks.

MACROSCOPIC STRUCTURE.—A peculiarity of this species is the production of the flower on a branch (not stem) of the same year's growth. The *flowers* have five oblong sepals, hairy beneath, five white or pink petals, also hairy beneath, a five-loculed ovary with numerous ovules, five independent styles, and about twenty stamens.

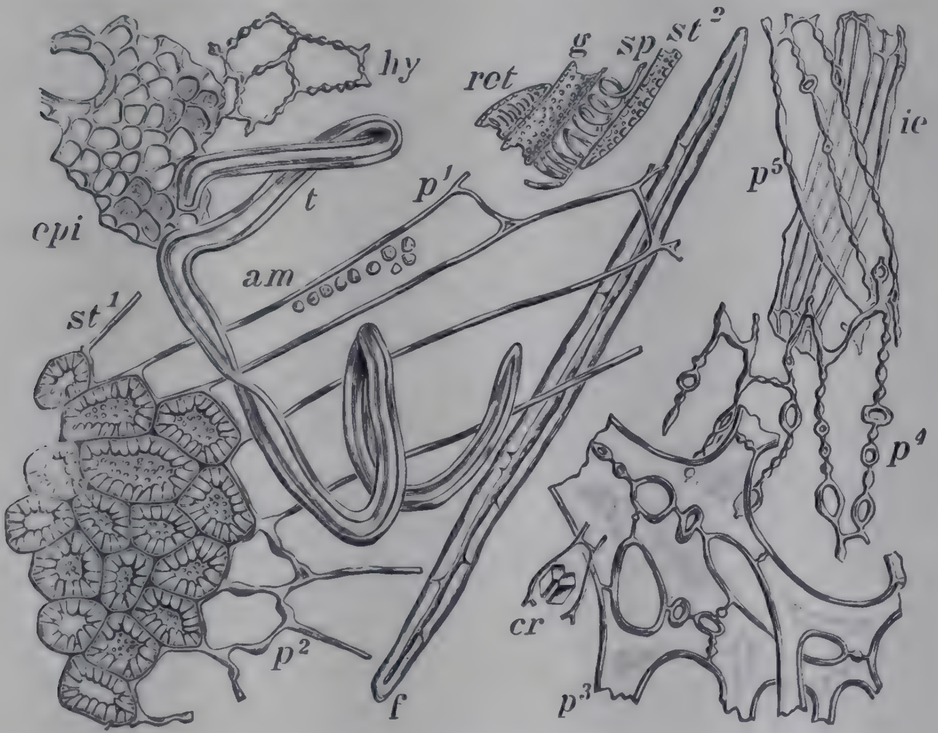

Fig. 204.—Quince. Elements of fruit in surface view. *epi* epiderm; *hy* hypoderm; st^1 stone cell group with p^1 radiating parenchyma, containing *am* starch grains, and p^2 thick-walled parenchyma; *f* bast fiber, *sp* spiral, *ret* reticulated, and *g* pitted vessels, and st^2 sclerenchyma cell of fibro-vascular bundle; p^3, p^4 spongy parenchyma and *cr* crystal cell of inner fruit flesh; p^5, *ie* crossing cells of endocarp. × 160. (K.B.W.)

Among the characters of the *fruit*, aside from its shape and golden color, are the absence of a stem, other than the branchlet at the end of which it is borne, the persistent calyx, the felted, loosely attached hairs over the whole surface, the hard flesh with large stone cell groups, the rather soft core, and the double row of *seeds* (up to fifteen) crowded in each locule.

MICROSCOPIC STRUCTURE.—The stone cells of the quince, as well as of the pear, were observed by very early botanists. Quince seed, being used in pharmacy, has been studied by Berg[1] and later pharmacognocists.

Fruit (Figs. 204 and 205).—The *epiderm* (*epi*) cells and cork spots are like those of the pear but the hairs (*t*) are strikingly different, being exceedingly kinky and with walls, although thickened, much narrower than the lumen. No difference in the *hypoderm* (*hy*) of the two fruits has been noted.

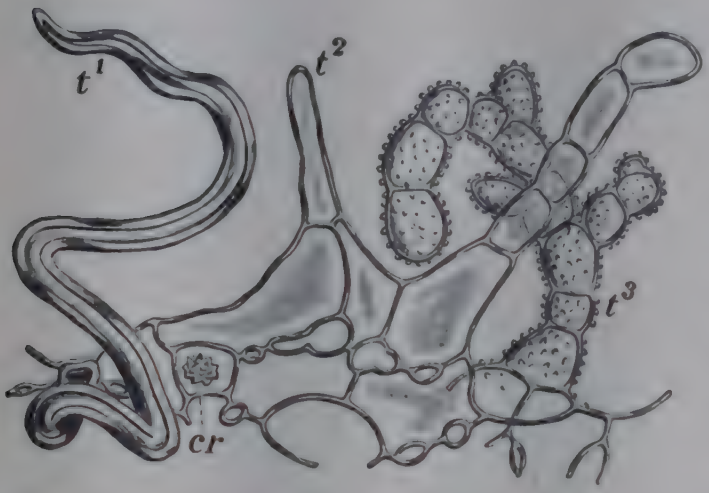

FIG. 205.—Quince. Epiderm of endocarp suture in cross section. t^1 thick-walled, t^2 thin-walled, and t^3 warty jointed hairs; *cr* crystal rosette. × 160. (K.B.W.)

As in the pear, the *stone cells* (st^1) of the fruit flesh are in groups surrounded by radiating *parenchyma* but the groups are usually larger, the parenchyma cells are more elongated (p^1), and sometimes have knotty, thickened walls (p^2). Starch grains up to 5 μ occur in the unripe fruit. *Spongy parenchyma* (p^3), containing occasional monoclinic *crystals* (*cr*), makes up the inner fruit flesh. This passes into elongated cells with small intercellular spaces (p^4), and this in turn into the endocarp. The *fibrovascular bundles* and accompanying *bast fibers* (*f*) and elongated *sclerenchyma cells* (st^2) are practically the same as those of the apple and pear.

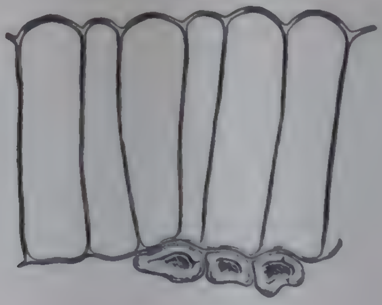

FIG. 206.

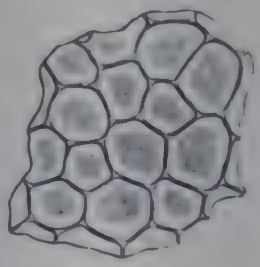

FIG. 207.

FIG. 206.—Quince. Outer epiderm and fibers of spermoderm in cross section. × 160. (K.B.W.)

FIG. 207.—Quince. Outer epiderm of spermoderm in surface view. × 160. (K.B.W.)

The *endocarp* consists of elongated cells (p^5) with beaded (porous), but not strongly thickened, walls crossing an innermost layer (*ie*) with thin, non-porous walls, the cells of which are narrower than in the pear.

[1] Anat. Atlas, Berlin, 1865, p. 92.

Hairs (Fig. 205) occur in the endocarp sutures as in the apple and pear. Thick-walled kinky forms (t^1), much like those on the epiderm of the ruit, are present in addition to thin-walled unicellular and jointed hairs (t^2) and branching, jointed, warty hairs (t^3) without sclerenchyma members such as are found in the pear and apple.

Spermoderm (Figs. 206 and 207).—Excepting the outer epiderm, the tissues are practically the same as in the apple. Characteristic of the *epiderm* is the radial elongation of the cells, which is more marked than in the pear, and the absence of sclerenchymatous thickening. In surface view, the cells are polygonal-isodiametric. As in other members of the group, they have a secondary thickening of *mucilage* which is here particularly abundant and renders the seed useful in medicine.

Perisperm, Endosperm, and **Embryo.**—As in apple and pear.

CHIEF STRUCTURAL CHARACTERS.—Fruit yellow, apple- or pear-shaped; hairs matted, loosely attached, over whole surface; fruit flesh hard with large stone cell masses; endocarp as in pear. Seeds very mucilaginous.

Epiderm hairs kinky, moderately thickened walls narrower than lumen; mesocarp stone cell groups large, radiating parenchyma cells long; endocarp much as in pear but cells of innermost layer narrower; suture hairs partly unicellular, thick- or thin-walled, straight or kinky, partly jointed, smooth or warty, without sclerenchyma members. Outer epidermal cells of spermoderm radially much elongated (polygonal in surface view), with mucilaginous but without sclerenchymatous thickening.

CHEMICAL COMPOSITION.—Analyses of the flesh of 3 samples of apple quince and 2 samples of pear quince grown in Austria, by Hotter,[1] show the following range:

COMPOSITION OF QUINCE FLESH (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Apple:										
Min...	14.2	4.6	10.0	0.7	5.3	2.0‡	6.3‡	0.11	0.06	0.41
Max...	19.0	7.1	13.6	1.0	8.2	2.0‡	6.3‡	0.16	0.07	0.73
Pear:										
Min...	19.9	6.7	14.2	0.9	8.1	2.1	6.0	0.77‡	0.07	0.47
Max..	20.2	7.3	14.3	1.2	8.9	2.4	6.5	0.77‡	0.08	0.54

* As invert. † Phosphoric acid: apple 0.06 to 0.09%; pear 0.05 to 0.07%. ‡ 1 sample.

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[1] Z. landw. Versuchsw. 1906, 9, 747.

Composition of Quince Juice.—Analyses of single samples of quinc juice have been made by Hotter,[1] Truchon and Martin-Claude,[2] an Windisch and Schmidt[3] as follows:

COMPOSITION OF QUINCE JUICE

(Grams per 100 cc.)

	Sp. gr. 15° C.	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Hotter	1.054	14.02	....	0.84	9.15	0.51	0.42	....	..
T. and M-C.	1.048	12.72†	....	0.86	7.59	0.00	....	0.42	..
W. and S.	1.051	13.29	0.32	1.43	7.82	0.67	0.27	0.39	37

* Cc. $N/10$ acid per 100 cc. juice. † Alcohol precipitate 0.46 per cent.

Fatty Oil of Seed.—Steger and Van Loon[4] by extraction of quince-seed kernels obtained a yield of 19.2 per cent of oil having the following values: specific gravity 15°/4° 0.9220, refractive index at 20° C. 1.4738, saponification number 194.2, iodine number (Wijs) 121.6, acetyl number 14.7, acid number 15.3, ester number 178.9, and thiocyanate number 82.7. It contained saturated acids 8.6, oleic acid 42.5, linolic acid 39.2, linolenic acid 3.9, volatile acids 1.44, glycerol radical 4.0, and unsaponifiable matter 0.36 per cent.

Mucilage.—Quince-seed mucilage, as hydrolyzed by Renfrew and Cretcher,[5] yielded cellulose 33 per cent, *l*-arabinose 2 per cent, and a mixture of aldobionic acids of which 72 per cent was methylated and 28 per cent unmethylated, passing on further hydrolysis to xylose.

Acids.—Truchon and Martin-Claude[6] conclude that, as in several other fruits, the acid is *tartaric*. Bigelow and Dunbar[7] quote results by Pratt showing in the fruit *malic acid* 1.00 per cent and citric acid none. Muttelet[8] found in the juice malic acid 1.10 per cent and citric acid none. Nelson[9] found malic but no citric acid.

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[1] Pomolog. Vers.-Stat. Graz, Jahresb. 1895/6, p. 10.

[2] J. pharm. chim. 1901, **13**, 171.

[3] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[4] Rec. trav. chim. 1934, **53**, 24.

[5] J. Biol. Chem. 1932, **97**, 503.

[6] Ann. chim. anal. 1901, **6**, 85.

[7] J. Ind. Eng. Chem. 1917, **9**, 762.

[8] Ann. fals. 1922, **15**, 453.

[9] J. Am. Chem. Soc. 1927, **49**, 1300.

Minor Mineral Constituents. *Iron.*—Edible portion 10.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[1]

Copper.—Edible portion 1.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[2]

MEDLAR

Mespilus germanica L. = *Pyrus germanica* L.

Fr. Nèfle. Sp. Nispero. It. Nespola. Ger. Mispel.

Two botanical varieties, the giant (*gigantea* Kirchn.) and the seedless (*abortiva* Kirchn. = *apyrena* Koch), in addition to the type, yield edible fruit. Hartwich[3] classes as a separate species the romance medlar (*M. Agarolus* L.), grown in southern Europe, which has only two or three stones.

The medlar grows wild and is cultivated in central and southern Europe and western Asia. Only after the fruit has been touched by frost while still on the tree and stored in the dark until fermentation and partial decay sets in is it edible raw. Even then it is quite acid. It is used for preserves and in making dark coarse cakes of insipid flavor eaten by children.

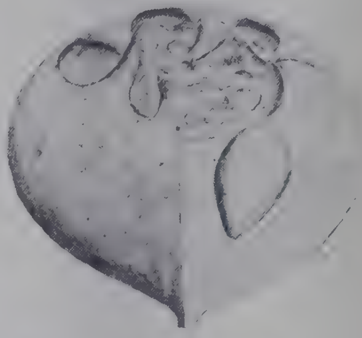

FIG. 208.—Medlar. Fruit. ×1. (A.L.W.)

MACROSCOPIC STRUCTURE.—Like those of the quince, the *flowers* are borne on branches of the same season's growth without peduncles. They have normally five calyx lobes, petals, ovary locules, and styles. There are two ovules in each locule.

The *fruit* (Fig. 208) is a pome but differs from the common pomes in that: (1) the calyx lobes are long and narrow, arching over the broad (2 cm. or more), flattened, depressed, hairy, disk-like top of the fruit; (2) the epiderm separates here and there in flakes; (3) the endocarp tissue is hard but thin-walled (up to 2 mm.), forming five stones about 1 cm. long which reach to and distend the top of the fruit. Hairs occur not only on the tip but also at the base of the fruit. Only one at most of the two ovules develops into a *seed* and many time snone, even when the stones are of normal size.

MICROSCOPIC STRUCTURE. Fruit.—The *epiderm* cells reach a maximum of 35 μ, or about the same limit as those of the pear and quince. They do not show by the thickness of the walls the division into daughter cells. The hairs are strongly sinuous, pointed, up to 1.5 mm. in length, with lumen as broad as or broader than the walls.

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[1] J. Biol. Chem. 1928, **78**, 215.

[2] Ibid. 1929, **82**, 465.

[3] Beythien, Hartwich and Klimmer: Handb. Nahrungsm.-Unters, Leipzig, 1915, **2**, 166.

Stone cells occur in great numbers in the outer fruit flesh, but they differ from those of the pear and quince in that they are much thinner-walled and occur only singly or in small groups. The cells of the fruit flesh *parenchyma* are sac-shaped containing small starch grains when not fully ripened, also here and there oxalate rosettes. Fibro-vascular bundles are few and delicate.

The *endocarp* is made up of small rounded stone cells and an inner fiber-like layer, with colorless walls and usually colorless contents.

Spermoderm.—In specimens grown in Austria, most of the seeds were found to be abortive, showing no definite structure. Some, however, were more or less perfect, the cells of the *outer epiderm* of the spermoderm being isodiametric, polygonal to longitudinally elongated in surface view, and flattened in cross section. The other layers, though not fully developed, corresponded with those of the apple.

Perisperm, Endosperm, and **Embryo.**—Often undeveloped.

CHIEF STRUCTURAL CHARACTERS.—Fruit broad, disk-like, depressed at top; calyx lobes long, narrow, incurved; stones five, formed by hard but thin endocarp. Seeds often abortive.

Epidermal cells of fruit about as large as in pear and quince but division into daughter cells not evident; hairs strongly sinuous, pointed, up to 1.5 mm. with lumen as broad as walls; single stone cells or small groups in fruit flesh; endocarp of small stone cells and an inner fiber-like layer. Structure of seed similar to that of apple.

CHEMICAL COMPOSITION.—Bersch[1] analyzed whole medlars, after ripening off the tree until the hard white flesh became brown, soft, and edible, also the different parts with results as given in the following table:

	Water	Protein	Fat	N-f. ext.	Invert sugar	Fiber	Ash
	%	%	%	%	%	%	%
Skin	63.14	1.52	0.98	26.77	.....	6.45	1.14
Flesh	75.21	0.65	0.14	21.37	12.04	1.82	0.81
Seeds	38.42	1.57	0.38	28.73	.....	29.88	1.02
Whole	69.13	0.86	0.32	23.79	11.14	5.03	0.87

In 2 samples of the flesh of Austrian medlars, Hotter[2] reports the following minimum and maximum results: total solids 26.5 to 28.4, nsoluble solids 9.7 to 11.2, extract 17.9 to 18.3, total sugars as invert 10.0 to 10.6, dextrose 3.8 to 4.1, levulose 6.3 to 6.6, sucrose 0.6 to 0.6, acids as malic 1.1 to 1.2, tannin 0.05 to 0.05, total ash 0.55 to 0.87, and phosphoric acid 0.06 to 0.08 per cent.

---

[1] Landw. Vers.-Stat. 1896, 46, 471.

[2] Z. landw. Versuchs. 1906, 9, 747.

Composition of Medlar Juice.—Windisch and Schmidt[1] analyzed the juice of 2 samples with results in terms of grams per 100 cc. summarized below:

	Sp. gr. 15° C.	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Min....	1.051	13.31	0.24	1.25	7.79	0.00	0.73	0.46	43
Max...	1.059	15.35	0.41	1.36	10.12	1.16	0.87	0.51	48
Aver...	**1.055**	**14.33**	**0.33**	**1.31**	**8.96**	**0.58**	**0.80**	**0.49**	**46**

* Cc. *N*/10 acid per 100 cc. juice.

Changes in Composition During Storage.—Notwithstanding the loss of moisture during storage (" after-ripening "), Bornträger[2] records also a percentage loss of both invert sugar and acids. The ripe, after-ripened, and over-ripened fruits contained respectively: 11.52, 10.78, and 8.79 per cent of invert sugar and 1.38, 1.02, and 1.00 per cent of acids calculated as malic ($C_4H_6O_5$).

Manaresi and Tonegutti[3] state that during after-ripening the acid content decreases and the tannin is rendered unobjectionable partly by respiration as claimed by Gerber[4] and partly by combination with protein according to the theory of Behrens.[5]

Changes in Composition Due to Freezing.—Otto and Kooper[6] give as the composition of medlars before and after freezing for 8 days the results tabulated below:

	Weight	Water	Protein	Acids as malic	Sugars, total*	Ash
	g.	%	%	%	%	%
Before freezing..........	14.5	74.14	5.38	1.22	11.46	....
After freezing...........	13.3	69.12	5.19	1.08	11.57	0.87

* All in the form of invert sugar.

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[1] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[2] Ibid. 1902, **5**, 145.

[3] Staz. sper. agr. ital. 1910, **43**, 369.

[4] Compt. rend. 1897, **124**, 1106.

[5] Zentr. Bakt. Parasitenk. II, **4**, 770.

[6] Z. Unters. Nahr.-Genussm. 1910, **19**, 328.

Acids.—Animal experiments by Caserio[1] indicate that the ripe medlar contains practically no *ascorbic acid.*

Minor Mineral Constituents. *Zinc.*—Whole fruit 1.9 mg. per kilo, fresh basis (Bertrand and Benzon).[2]

SORB

Sorbus spp.

Fr. Sorbier des oiseaux. Sp. Roan. It. Sorbo de'cacciatori.
Ger. Vogelbeere.

The fruits of several species or varieties of the European mountain ash or rowan tree are used for making various sweetmeats.

MACROSCOPIC and MICROSCOPIC STRUCTURE.—No authentic material available for study.

CHEMICAL COMPOSITION.—Analyses by Otto and Kooper[3] of the over-ripe fruit of *S. rossica* (*S. Aucuparia* L. var. *rossica* Spaeth) and *S. moravica* (*S. Aucuparia* L. var. *moravica* Zeng. = var. *dulcis* Kraetzl) show respectively as follows: weight 0.25 and 0.3 gram, water 72.53 and 71.35, acids as malic 3.09 and 1.85, total sugars as invert 9.15 and 8.95, sucrose 0 and 0.31, and tannin and color 0.52 and 0.75 per cent.

Bornträger[4] found 14.42 and 11.20 per cent of invert sugar and 0.41 and 0.25 per cent of acids respectively in fresh and ripened fruits of the closely related service tree (*S. domestica* L.). In over-ripened fruit an increase of sugars to 13 per cent was noted.

More complete analyses are those of the flesh of 3 samples each of Eberesche (*S. aucuparia*) and Speierling (*S. domestica*) given by Hotter[5] as summarized on the next page.

Analyses by Nuccorini and Bartoli[6] show the following composition (dry basis) at the beginning of ripening and at complete ripeness: soluble matter 12.29 and 37.72, dextrose 2.57 and 16.67, levulose 1.58 and 12.50, sucrose 0.17 and 1.50, sorbitol 0.42 and 0.26, and free acids calculated as malic 2.20 and 9.00 per cent. On the tree the sorbitol reached a maximum of 3.54, but after picking this was reduced to 0.26. owing to change to dextrose and levulose, not sorbose.

[1] Z. Vitaminforsch. 1934, **3**, 93.

[2] Bul. soc. hyg. aliment. 1928, **16**, 457.

[3] Z. Unters. Nahr. Genussm. 1910, **19**, 328.

[4] Ibid. 1902, **5**, 145.

[5] Z. landw. Versuchsw. 1906, **9**, 747.

[6] Boll. ist. super. agr. Pisa 1932, **8**, 277.

Composition of Sorb Flesh (Hotter)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Eberesche:										
Min.....	24.6	6.4	16.2	1.6	5.5	2.3	3.1	0.3	0.20	0.72
Max....	27.7	9.2	21.9	2.7	8.0	3.8	4.3	0.7	0.27	0.84
Speierling:										
Min.....	29.9	12.0	17.7	0.6	12.1	1.8	8.3	0.8	0.03	0.60
Max....	31.3	14.5	18.3	0.6	13.7	4.7	11.8	1.7	0.74	0.68

* As invert. † Phosphoric acid: Eberesche 0.08 to 0.14%; Speierling 0.03 to 0.14%.

Acids.—V. Euler[1] states that the *ascorbic acid* in the sorb (*S. aucuparia dulcis*) may in extreme cases be double that in the tomato or citrus fruits.

HAWTHORN

Cratægus spp.

Fr. Cenelle. Sp. Espino blanco. It. Bacca di bianco spino.
Ger. Mehlbeere.

The fruits or "haws" of some of the numerous species of this large and bewildering genus are used to some extent for making preserves and sweetmeats.

MACROSCOPIC and MICROSCOPIC STRUCTURE.—In view of the numerous species and the small importance of those used as foods, structural studies seem unwarranted.

CHEMICAL COMPOSITION.—A single analysis by Otto and Kooper[2] of the over-ripe fruit of *C. coccinea* is here given as illustrative of the group:

Weight	Water	Acids as malic	Invert sugar	Sucrose
g.	%	%	%	%
2.5	72.74	0.81	7.84	0.12

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[1] Arkiv. Kemi, Mineral. Geol. 1933, **11B**, No. 18; Chem. Abs. 1934, **28**, 2035.

[2] Z. Unters. Nahr.-Genussm. 1910, **19**, 328.

LOQUAT

Eriobotrya japonica Lindl. = *Photinia japonica* Gray =
Cratægus Bibas Lour.
Fr. Nèfle du Japon. Sp. Nispero del Japón.
It. Nespola di Giapponne. Ger. Japanische Mispel.

Meyer[1] believes the loquat to have originated in China. Since ancient times it has been cultivated in both China and Japan, being a fruit of first importance. The tree grows luxuriantly in the Mediterranean region, the Azores, California, and Florida.

The loquat is the sub-tropical substitute for the apple.

MACROSCOPIC STRUCTURE.—Like those of other pomes, the *flowers* (1 cm.) are five-merous with inferior ovary. They have five acute calyx lobes, five rounded white petals, twenty stamens, and a two- to five-loculed ovary, each locule with two ovules.

The *fruit* (Fig. 209) is yellow or orange, 3 to 7 cm. long, pear- or plum- shaped, with persistent calyx lobes, a thin skin, a fruit flesh up to 12 mm. thick, a membranous endocarp, and one to five, commonly three, seeds, separated by membranous dissepiments, one and sometimes both the seeds in each locule being abortive. Numerous hairs occur at the two ends, but only a few on the body of the fruit.

The *seeds* (Fig. 209) are 1 to 2 cm. long, ovate, smooth, dark brown, with a thin, leathery spermoderm closely investing an embryo with two fleshy cotyledons.

MICROSCOPIC STRUCTURE. Fruit.—A study of the tissues shows that (1) the *epidermal cells* resemble those of the apple, while the hairs are much like those of the quince, (2) the *fruit flesh* contains stone cells, but generally these occur singly or in pairs and not as in the pear, quince, and medlar in groups, and (3) the *endocarp* is of exceedingly thin-walled elongated cells.

The cells of the *epiderm* are polygonal, up to 50 μ in diameter, showing indistinct beads and distinct division of mother cells into daughter cells. Stomata occur sparingly. As in the quince, the *hairs* are long, pointed, and strongly sinuous or kinky, with lumen usually broader than walls.

In the *outer fruit flesh* the parenchyma cells are large and sac-like, containing here and there oxalate rosettes but no starch at maturity. The *stone cells* have colorless, strongly thickened walls. Though mostly occurring singly, groups of two have been observed. As in other pomes, the *inner fruit flesh*, several cells thick, consists of spongy parenchyma.

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[1] U. S. Dept. Agr., Bur. Plant Ind. 1911, Bul. **204**, 35.

The dissepiments consist of spongy parenchyma between the endocarp layers.

A marked distinction from other pomes lies in the cells of the *endocarp* which have exceedingly thin walls. The layer is colorless, one cell thick, and the elongation is in different tangential directions.

Spermoderm (Fig. 210, *S.*).—The structure differs widely from that of other pomes. Only three layers are evident: (1) *outer epiderm* (*aep*) of polygonal cells with exceedingly delicate, hardly visible primary walls and secondary mucilaginous thickenings; (2) *spongy parenchyma* (*br*) with somewhat thickened brown walls, forming a layer 300 to 500 μ thick, through which run the raphe bundles (*fv*); and (3) colorless *compressed parenchyma* (*p*) without evident differentiation of an inner epiderm.

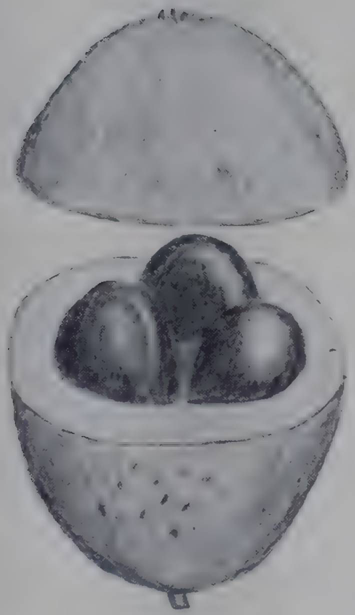

Fig. 209.

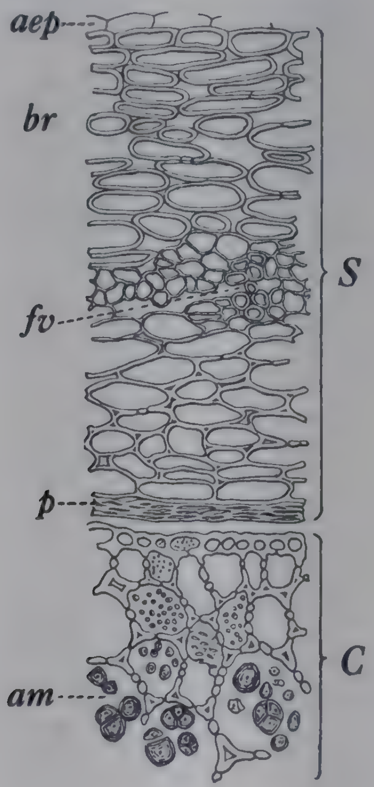

Fig. 210.

Fig. 209.—Loquat. Three-seeded fruit cut transversely at center showing seeds entire. × 1. (A.L.W.)

Fig. 210.—Loquat. Seed in cross section. *S* spermoderm: *aep* outer epiderm, *br* brown parenchyma, *fv* fibro-vascular bundle, *p* compressed parenchyma. *C* cotyledon with *am* starch grains. × 160. (K.B.W.)

Perisperm and **Endosperm.**—Neither is evident at maturity. Possibly one or both are included in the structureless band forming the inner tissue of the spermoderm.

Embryo.—A remarkable character of the *cotyledons* (Fig. 210, *C*) is the presence, in the thick-, porous-walled mesophyl, of starch grains (*am*) of the tapioca type, up to 10 μ, occurring commonly in aggregates of two to four individuals. A hilum is evident. No other seed of the rosaceous species described in this work contains starch in the embryo.

CHIEF STRUCTURAL CHARACTERS.—Fruit pear- or plum-shaped, yellow or orange; locules one to five; endocarp thin, soft. Seeds 1 to 2 cm. long; spermoderm brown, leathery; cotyledons fleshy.

Epidermal cells of fruit polygonal, up to 50 μ, mother and daughter cells marked; hairs long, sinuous, with lumen broader than walls; stone cells of fruit flesh occurring singly or as twins; endocarp cells elongated, very thin-walled. Outer epidermal cells of spermoderm polygonal with mucilaginous secondary thickening but no tertiary thickening; parenchyma brown, bulky. Perisperm and endosperm lacking. Cotyledons unique among rosaceous fruits in having thick-, porous-walled cells with starch grains of the tapioca type, up to 10 μ.

CHEMICAL COMPOSITION.—Condit[1] gives analyses by Jaffa of the flesh (edible portion) of 2 varieties of loquat, Thales and Champagne, grown in California. The fruit consisted of pulp 70 and 62, seed 15 and 18, and skin and core 15 and 20 per cent respectively.

COMPOSITION LOQUAT PULP (JAFFA)

	Water	Protein	Fat	Dextrose	Sucrose	Fiber	Ash	Undeter.
	%	%	%	%	%	%	%	%
Thales........	89.0	0.35	0.06	8.95	0.94	0.30	0.29	0.11
Champagne....	85.0	0.32	0.03	11.96	0.83	0.37	0.36	1.11

Bornträger[2] found in terms of grams in 100 cc. of the juice of unripe, partly ripe, and fully ripe fruit respectively: invert sugar 2.74, 4.20, 6.00; sucrose 4.30, 2.47, 4.94; and acids as malic 1.75, 0.84, 0.60 per cent. Similar results were obtained by Traetta-Mosca, Papocchia, and Galimberti.[3]

Kursanov[4] states that dextrose and citric acid in the pericarp increase, the former only slightly, during the early stages of ripening but later decrease. As ripening proceeds, maltose, tartaric acid, and amygdalin almost completely disappear, dextrin, starch, hemicellulose, cellulose, proteins, and non-protein nitrogenous substances decrease,

[1] California Agr. Exp. Sta. 1915, Bul. **250**.

[2] Z. Unters. Nahr.-Genussm. 1902, **5**, 145.

[3] Ann. chim. appl. 1923, **13**, 333.

[4] Planta 1932, **15**, 752; (Abt. E. Z. wiss. Biol.).

the chief substances present at full ripening being levulose, sucrose, and malic acid. In the seed dextrin remains constant, amygdalin, starch, hemicellulose, and cellulose increase, and nitrogenous substances decrease during ripening.

A paper by Church and Sorber, entitled "The Chemical Composition of the Loquat," was read at the New York Meeting of the American Chemical Society, April 22, 1935.

Acids.—Traetta-Mosca et al.[1] report *malic*, *citric*, *tartaric*, and *succinic acids*, but their findings need confirmation in view of their disagreement with other authors as to the acids of the apricot and cherry.

Glucosides.—Herissey[2] isolated *amygdalin* in crystalline form from an alcoholic extract of the kernel. Previous investigators had noted the liberation of hydrocyanic acid on treatment with emulsin.

Enzymes.—Traetta-Mosca and co-workers[3] detected *oxidase* and *peroxidase* in the unripe loquat but not in the ripe fruit. *Invertin*, *amylase*, and *emulsin* occurred at all stages of development.

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[1] Loc. cit.

[2] J. pharm. chim. 1906, [6], **24**, 355.

[3] Loc. cit.

II. STRAWBERRIES

(*Potentilleæ*)

ONLY one genus, *Fragaria*, the species of which are collectively known as strawberries, is represented. The large succulent receptacle is the valuable portion of the fruit, the achenes, or fruits proper, being small, dry, and hard.

COMPARATIVE MACROSCOPIC STRUCTURE.—Classified according to the fruit, the species fall into two groups: (1) those having achenes sunken in the receptacle and (2) those having achenes not sunken in the receptacle. American varieties belong in the first group, European varieties in the second group.

COMPARATIVE MICROSCOPIC STRUCTURE.—The structure of the American strawberry as given below fairly represents the whole group.

COMPARATIVE CHEMICAL COMPOSITION.—Reducing sugars exceed sucrose in amount. The acid consists chiefly of citric with a small amount of malic.

AMERICAN STRAWBERRY

Fragaria chiloensis Duchesne

Fr. Fraise du Chili. Ger. Ananaserdbeere.

Bailey[1] divides American strawberries into three groups: (1) the Virginian group including the common Eastern field and meadow species, *F. virginiana* Duchesne and its varieties, (2) the vesca group, including the European alpine species (*F. vesca* L.) and the American wood strawberry (*F. vesca* var. *americana* Porter), and (3) the Chilean group, including the wild species of the Pacific Coast and the common American garden varieties.

Epicures are well agreed on giving the strawberry the first place among small fruits. Strawberry jam is also delicious, especially if made from wild fruit. Crushed strawberries and strawberry syrup are much used in soda-fountain beverages and ice cream.

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[1] Evolution of our Native Fruits, London, 1898, pp. 428–432.

MACROSCOPIC STRUCTURE.—Characteristic of the genus is the succulent *receptacle* constituting the valuable part of the fruit.

The *flower* has five bracts alternating with five calyx lobes, five white petals, numerous short stamens borne on a disk, and numerous one-ovuled pistils, with style arising from near the base on the ventral side, borne on the receptacle. On ripening, the bracts and calyx lobes persist without withering and the receptacle becomes much enlarged.

In the Chilean and Virginian groups, the *achenes* (Fig. 211, II and III) are borne in depressions on the receptacle (I); in the vesca group, there are no depressions. The outer receptacle tissues are usually red and of different texture from the white pith. Between the two run the main bundles from which secondary bundles shoot off to the achenes. The achenes are ovoid, about 1 mm. long. The styles are about 2 mm. long, narrowed at the base. A cross section of the achene (IV) shows the dry, shell-like pericarp (*F*) and a thin skin consisting of spermoderm (*S*) with raphe (*R*), perisperm, and endosperm (*E*) enveloping the embryo (*Em*) with two large cotyledons.

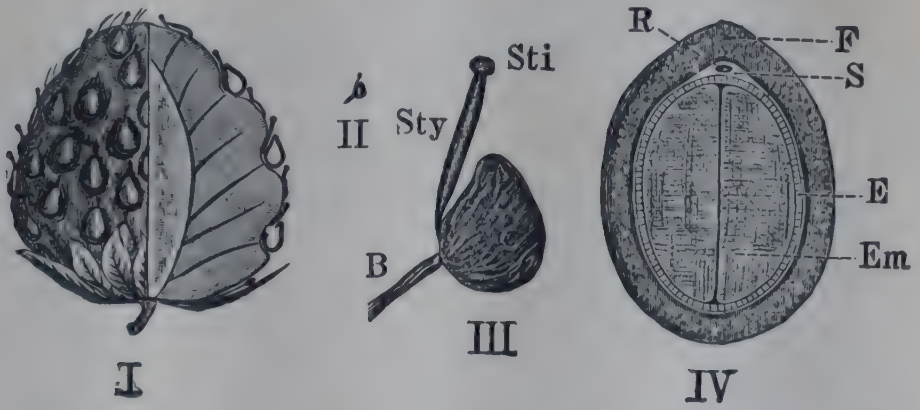

Fig. 211.—Strawberry. I aggregate fruit, × 2. II achene, × 1. III achene: *Sty* style; *Sti* stigma; *B* connecting bundle. × 8. IV achene in cross section: *F* pericarp; *S* spermoderm; *R* raphe; *E* endosperm; *Em* embryo. × 32. (A.L.W.)

MICROSCOPIC STRUCTURE.—Kraus[1] studied the pericarp and Tschierske[2] all the tissues but those of the seed. Blyth[3] and Marpmann[4] describe certain tissues found in jams. Winton[5] describes all the tissues.

Receptacle (Fig. 212).—Following the nomenclature of stems, the five tissue zones are (1) *epiderm* (*ep*) of polygonal cells, stomata (*sto*), and long, pointed, thick-walled hairs (*h*); (2) *hypoderm* (*hy*) of meristematic cells, without intercellular spaces, which form by cell division the bulk of the berry; (3) *cortex* or fruit flesh of rounded cells with intercellular spaces; (4) *bundle zone* with spiral and annular vessels; and (5) *pith* of thin-walled cells, often torn asunder during growth leaving large cavities.

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[1] Prings. Jahrb. wiss. Bot. 1866, **5**, 83.

[2] Z. Naturwiss. 1886, **59**, 594.

[3] Foods, etc., London, 1909, p. 133.

[4] Z. angew. Mik. 1896, **2**, 97.

[5] Z. Unters. Nahr.-Genussm. 1902, **5**, 785; Connecticut Agr. Exp. Sta. Rep. 1902, p. 288.

Tschierske was the first to show that the cells of the hypoderm by division form the fruit flesh. This tissue, which he named the sarkogen layer, resembles cork but it forms new cells on the inner, not the outer, side and remains active throughout the whole period of growth. The cells, like cork cells, divide by tangential partitions. Both the outer and inner cells thus formed increase in size, the outer holding to its original form and the inner soon becoming the typical round cells of the cortex with marked intercellular spaces.

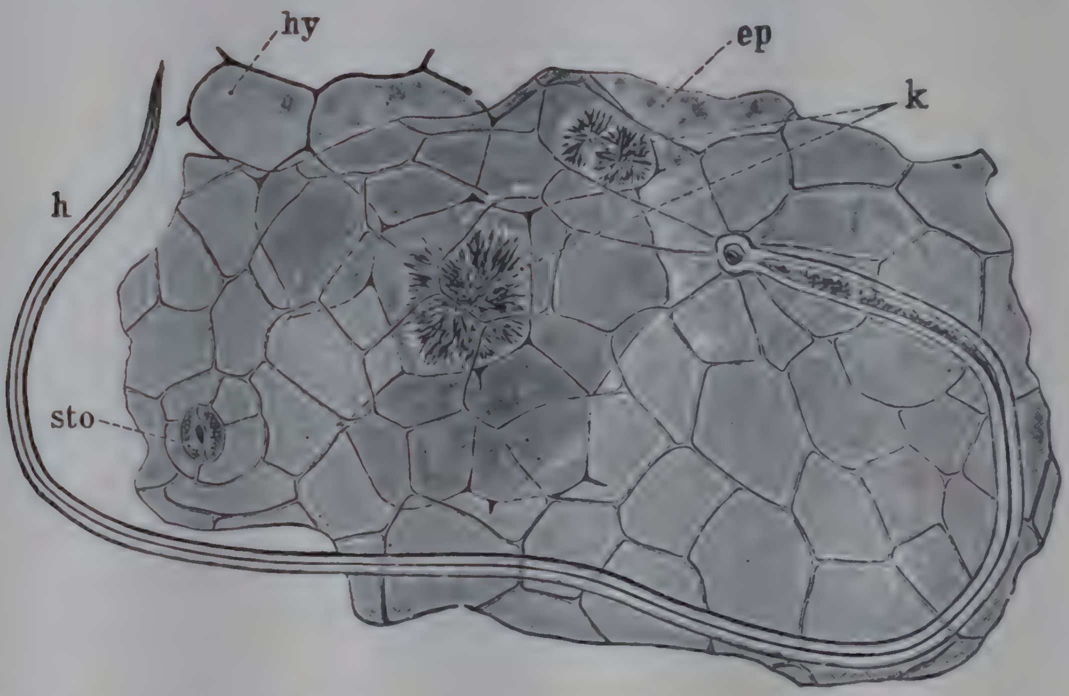

Fig. 212.—Strawberry. Receptacle in surface view. *ep* epiderm with *h* hair and *sto* stoma; *hy* hypoderm; *k* glucoside (?) crystals. × 160. (A.L.W.)

Style and **Stigma** (Figs. 213 and 214).—With low magnification, the style is readily distinguished from the styles of bramble berries by the constricted base. With higher magnification, the large size and transparency of the epidermal cells (*ep*) are noticeable. Through these the underlying tissues are readily seen, the central cylinder appearing darker than the outer tissues. Spiral (*sp*) and annular vessels, also accompanying crystal cells (*k*) with oxalate rosettes, are evident on clearing with chloral or sodium hydroxide. Papillæ make up the *stigma*. Fungous threads are often present in great numbers obscuring the structure.

Pericarp (Fig. 215, *F*).—Cross sections show four layers: (1) *epicarp* (*epi*) of quadrilateral cells which in surface view are polygonal, (2) *mesocarp* (*mes*) of only one or two rows of thin-walled cells with the transverse branches of the fibro-vascular bundles in the inner side, (3) *crystal cells* (*k*), each with a single monoclinic crystal, forming a single row, and (4) *endocarp* of four or five outer rows of longitudinal sclerenchyma fibers (*lf*) and one or two inner rows of transverse sclerenchyma fibers (*qf*).

On the dorsal side of the achene, some of the fibers of the inner endocarp extend radially through the outer endocarp, a provision that aids in splitting the tissues during sprouting.

Spermoderm (Fig. 215, *S*; Fig. 216).—Only two layers, each one cell thick, are evident except about the raphe. The outer layer or *outer epiderm* (*ep*) consists of remarkable spiral-reticulated cells with thickenings on the inner and radial walls but not on the outer walls. These cells are characteristic of *Fragaria* and do not occur in any of the other edible rosaceous fruits herewith described. A layer of transversely elongated, *brown cells* (*br*), arranged side by side in rows, immediately adjoins the outer epiderm.

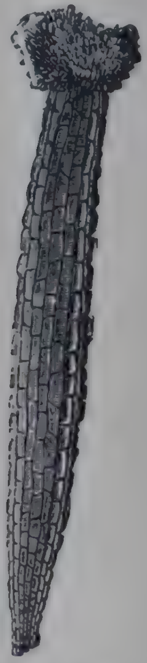

FIG. 213.

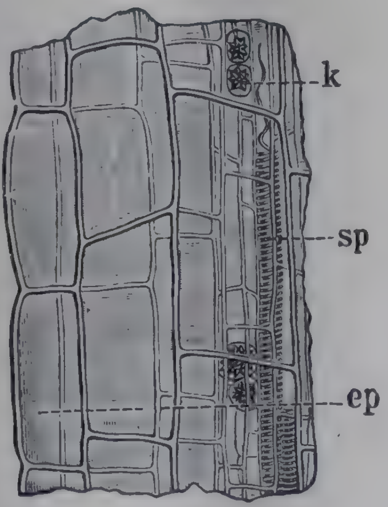

FIG. 214.

FIG. 213.—Strawberry. Style and stigma. × 32. (A.L.W.)

FIG. 214.—Strawberry. Style in surface view. *ep* epiderm; *sp* spiral vessels; *k* crystal cells. × 300. (A.L.W.)

Perisperm (Fig. 215, *N*).—A thin membrane-like layer consisting of *compressed cells* adheres on the one side to the spermoderm, on the other to the endosperm.

Endosperm (Figs. 215 and 216, *E*).—*Aleurone cells* form a single layer.

Embryo.—The bulk of the seed consists of the *cotyledons* with thin-walled cells containing small *aleurone grains* and *fat.*

Chief Structural Characters.—Receptacle fleshy and succulent. Achenes ovoid, in depressions; styles constricted at base, attached near base of achenes; pericarp with hard endocarp. Spermoderm, perisperm, and endosperm thin; cotyledons bulky.

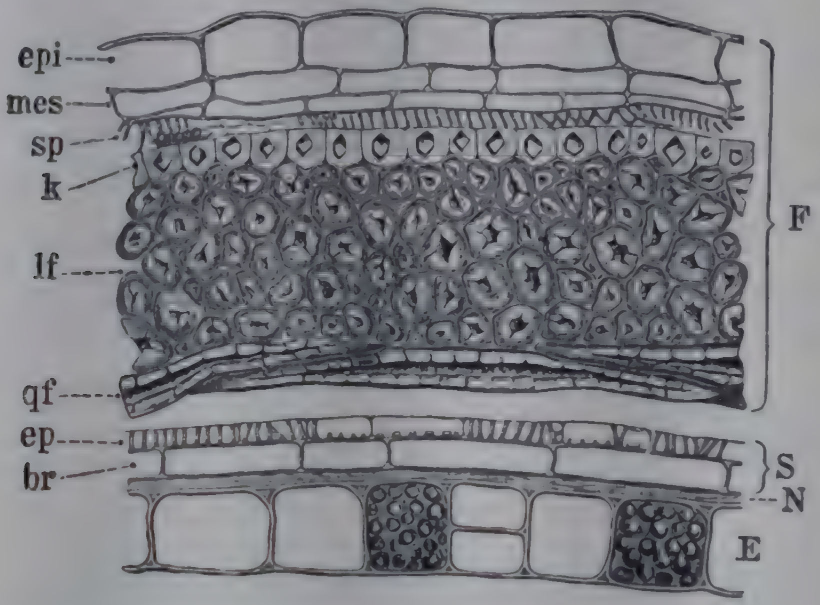

Fig. 215.—Strawberry. Achene in cross section. *F* pericarp: *epi* epicarp, *mes* mesocarp, *sp* spiral vessels, *k* crystal layer, *lf* longitudinal and *qf* transverse fibers of endocarp. *S* spermoderm: *ep* outer epiderm, *br* brown layer. *N* perisperm. *E* endosperm. × 300. (A.L.W.)

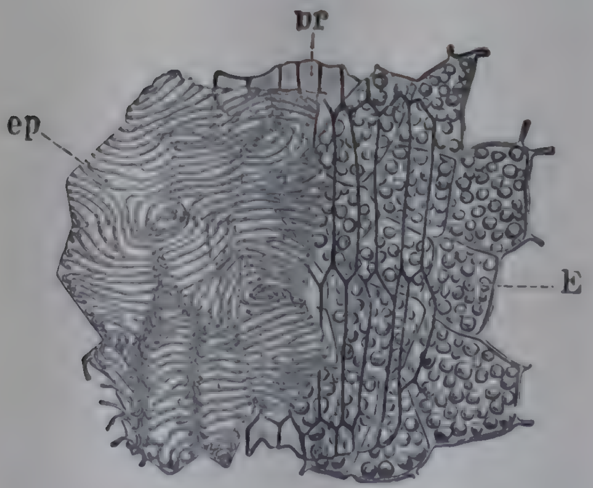

Fig. 216.—Strawberry. Outer seed tissues in surface view. Spermoderm: *ep* outer epiderm, *br* brown layer. *E* endosperm. × 300. (A.L.W.)

Epiderm of style of large transparent cells. Epiderm of receptacle with long, pointed, thick-walled hairs. Epicarp and mesocarp of thin-walled, polygonal cells; third layer of pericarp of crystal cells; endocarp of crossing layers of sclerenchyma fibers. Outer epiderm of spermoderm of spiral-reticulated, inner layer of transversely elongated cells. Endosperm of single aleurone layer. Cotyledons containing aleurone grains and fat.

CHEMICAL COMPOSITION (European and American species).—The table below shows analyses by Buignet[1] of the fruit of several species native to Europe and America, also summaries of analyses of American cultivated berries by Stone,[1] Shaw,[2] and Munson, Tolman, and Howard,[3] and of European berries by Olig.[4] The " hulls " (sepals), which in Stone's berries formed 2.41 to 5.53 aver. **3.34** per cent of the whole, were presumably removed in preparing the samples. Shaw's berries contained 1.04 to 2.27, aver. **1.52** per cent of crude fiber. It need hardly be stated that no general conclusion should be based on the single analyses of the individual species, although it would appear that the small wild berries are less succulent than those of the large-fruited cultivated varieties.

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[1] J. pharm. chim. 1859, [3], 36, 170.

Composition of Strawberries

	Samples	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, reducing	Sucrose	Alcohol ppt.	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	%	cc.
Buignet:										
F. elatior...	1	14.21	....	1.44	0.56	6.07	2.94	....	0.94	...
F. virginiana	1	17.95	....	1.56	0.75	11.12	....	....	1.15	...
F. vesca (?).	1	16.40	....	1.37	0.68	8.03	1.26	....	1.26	...
F. Collina..	1	17.71	....	2.27	0.57	4.98	6.33	....	1.45	...
F. chiloensis	1	11.96	....	0.73	0.60	7.13	1.07	....	1.02	...
Stone:	20									
Min.......		7.57	....	0.72	1.10	3.91	0.02	....	0.37	...
Max.......		12.28	....	1.23	1.99	6.71	1.17	....	0.82	...
Aver.......		**9.48**	....	**0.97**	**1.43**	**4.78**	**0.58**	....	**0.61**	...
Shaw:	9									
Min.......		8.48	....	0.62†	0.19‡	3.07§	0.62§	....	0.25	...
Max.......		18.30	....	1.12†	1.12‡	5.44§	1.59§	....	0.66	...
Aver.......		**11.43**	....	**0.86**†	**0.78**‡	**3.79**§	**1.02**§	....	**0.41**	...
Munson et al.:	5									
Min.......		6.85	2.57	0.47	1.05	2.72	0.09	0.48	0.51	48
Max.......		12.88	5.67	0.74	1.72	3.94	1.43	0.56	0.76	101
Aver.......		**8.74**	**3.39**	**0.59**	**1.31**	**3.22**	**0.46**	**0.51**	**0.62**	**63**
Olig:	3									
Min.......		9.96	2.06	....	1.21‖	5.11	0.11‖	....	0.50	38
Max.......		12.57	2.89	....	1.49‖	6.60	0.26‖	....	0.62	51
Aver.......		**10.98**	**2.47**	....	**1.35**‖	**5.71**	**0.19**‖	....	**0.56**	**45**

* Cc. *N*/10 acid per 100 grams of fruit. † 7 samples. ‡ 8 samples. § 5 samples. ‖ 2 samples.

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[1] Tennessee Agr. Exp. Sta. Bul. 1889, **2**, 69.

[2] Oregon Agr. Exp. Sta. 1900, Bul. **62**.

[3] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **66** rev.

[4] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

The following analyses of the pulp of 5 samples of strawberries are by Hotter:[1]

COMPOSITION OF STRAWBERRIES (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Min....	16.6	6.9	10.1	1.2	5.0	2.4	2.6	0.2	0.29	0.62
Max....	20.5	8.9	12.3	1.5	7.1	3.3	3.8	0.8	0.48	0.99

* As invert. † Phosphoric acid 0.09 to 0.15%.

Composition of Wild and Cultivated Strawberries.—Vercier[2] analyzed the fruit of wild strawberries and 16 cultivated varieties with the results given below. The variation in color was 1:2.

COMPOSITION OF WILD AND CULTIVATED STRAWBERRIES

	Weight per fruit	Solids per 100 g.	Juice per 100 g.	In 100 cc. Juice	
				Acids as citric	Sugars
	g.	g.	g.	g.	g.
Wild............	0.50	46.4	53.6	1.23	9.0
Cultivated:					
Min..........	3.30	14.0	54.3	0.67	6.4
Max..........	9.46	45.7	86.0	1.30	8.6

Composition of Strawberry Juice.—A summary of 29 analyses of strawberry juice by Windisch and Schmidt[3] follows on the next page.

Respiration.—Gore,[4] working with 2 varieties of strawberries, noted a maximum evolution of 151 mg. of carbon dioxide per kilo per hour at 26.2° C. and a minimum of 17 mg. at 2° C.

The ratio of CO_2 to O_2 of varieties with firm flesh was found by Overholser, Hardy, and Locklin[5] to be greater than that of varieties with soft flesh. The ratio and intensity increased with the advance of the season.

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[1] Z. landw. Versuchsw. 1906, **9**, 747.

[2] Prog. agr. vit. 1929, **92**, 281.

[3] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[4] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[5] Plant Physiol. 1931, **6**, 549.

COMPOSITION OF STRAWBERRY JUICE (WINDISCH AND SCHMIDT)

(Grams per 100 cc.)

	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Min. . .	1.023	5.92	0.18	0.58	3.03	0.00	0.13	0.32	34
Max. . .	1.046	11.96	0.37	0.94	7.75	0.54	0.13	0.60	64
Aver. . .	**1.030**	**7.71**	**0.26**	**0.71**	**4.46**	**0.24**	**0.13**	**0.43**	**48**

* Cc. $N/10$ acid per 100 grams of juice. 2 samples.

Fatty Oil of Seed.—The "seed" contains a drying oil similar to that of the blackberry and raspberry (which see). The data on the values of the oil are meager and discordant.

Acids.—Truchon and Martin-Claude[1] give *tartaric* as the acid of the strawberry, Kunz and Adam[2] give *citric*, and Muttelet[3] gives citric with traces only of tartaric. In a later paper Muttelet[4] reports 1.05 and 1.12 per cent of citric acid in 2 varieties. Paris[5] found citric together with a small amount of *malic acid*, and Nelson[6] confirmed his findings by the ester distillation method, about 90 per cent being citric and 10 per cent *l*-malic acid. Bigelow and Dunbar[7] reviewed the literature up to 1917 but do not appear to have studied this fruit themselves.

Mineral Constituents.—Kulisch[8] and Haskins[9] report percentages in the fresh fruit as given in the following table:

	Water	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5
	%	%	%	%	%	%	%
Kulisch.	86.50	0.667	0.313	. . . .	0.070	0.043	0.084
Haskins.	. . . . .	0.52	0.26	0.02	0.07	0.04	0.10

[1] Ann. chim. anal. 1901, **6**, 85.
[2] Z. allgem. oesterr. Apoth-Ver. 1906, **44**, 187.
[3] Ann. fals. 1909, **2**, 383.
[4] Ibid. 1922, **15**, 453.
[5] Chem. Ztg. 1902, **26**, 248.
[6] J. Am. Chem. Soc. 1925, **47**, 1177.
[7] J. Ind. Eng. Chem. 1917, **9**, 762.
[8] Z. angew. Chem. 1894, p. 148.
[9] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

Minor Mineral Constituents. *Iron.*—Edible portion 9 mg. per kilo, fresh basis (Bunge).[1] Edible portion 6.6 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Aluminum.—Berries and calyx 158 mg. per kilo, dry basis (Bertrand and Lévy).[3]

Copper.—Edible portion 0.2 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

Zinc.—Edible portion 0.9 mg. per kilo, fresh basis (Bertrand and Benzon).[5]

EUROPEAN STRAWBERRY

Fragaria vesca L.

Fr. Fraise. Sp. Fresa. It. Fragola. Ger. Walderdbeere.

The common wild or alpine strawberry of Europe is the type of this species from which have been derived cultivated varieties that bear fruit throughout the greater part of the season and in this respect resemble the " ever-bearing " varieties derived from the Chilean species.

Another and more hairy wild European species of the vesca type, the parent of certain cultivated varieties, is the hautbois (*F. moschata* Duchesne = *F. elatior* Ehrh.).

Wild strawberries are more industriously gathered in Europe than in America owing to the cheaper labor. They are sold in market places and served as delicacies in hotels.

MACROSCOPIC STRUCTURE.—Berries of the vesca type bear the *achenes* flush with the surface and not in depressions.

MICROSCOPIC STRUCTURE.—As in the American strawberry.

CHEMICAL COMPOSITION.—See American Strawberry.

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[1] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Compt. rend. 1931, **192**, 525.

[4] J. Biol. Chem. 1929, **82**, 465.

[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

III. BRAMBLE BERRIES

(*Rubeæ*)

All the common bramble berries belong in the genus *Rubus*. The cultivated varieties of the raspberry and the blackberry in Europe and America are largely derived from native species. Cultivated dewberries are more distinctly American, while the loganberry is a hybrid of a European raspberry and an American blackberry. The cloudberry is a cosmopolitan sub-artic species. The wineberry is an importation from Japan. The taxonomy of the genus is much confused.

COMPARATIVE MACROSCOPIC STRUCTURE.—Only one of the two ovules of each pistil develops into a seed. The aggregate *fruit* consists of numerous or several drupelets closely crowded on the receptacle. It has a juicy mesocarp free from stone cells, a hard endocarp, a thin spermoderm, perisperm, and endosperm, the latter, however, relative to the size of the embryo, being thicker than in the drupes.

Classified according to the berries, there are two groups: (1) drupelets loosely attached to receptacle, separating as a thimble-shaped aggregate (raspberry, wineberry), and (2) receptacle closely attached to drupelets and picked with them (blackberry, dewberry, loganberry, cloudberry). In both groups there are hairy and smooth members. The raspberry and loganberry, which are hairy on the exposed surface, are smooth below, whereas the wineberry, which is smooth on the exposed surface, is hairy below. The blackberry is smooth throughout; the dewberry and cloudberry are nearly smooth.

Long *styles* (about 3.5 to 4 mm.) occur on the raspberry, loganberry, and cloudberry, short styles (about 2 mm.) on the blackberry, dewberry, and wineberry. The *drupelets* and *stones* are largest in the cloudberry but are larger in the blackberry, dewberry, and loganberry than in the raspberry and wineberry. The stone is smooth in the cloudberry, furrowed like a peach stone in the other species.

COMPARATIVE MICROSCOPIC STRUCTURE. **Styles.**—The *epiderm* is wrinkled in the raspberry, loganberry, and wineberry, practically smooth in the blackberry, dewberry, and cloudberry.

Pericarp.—The *epicarp cells* of the blackberry and dewberry are transversely elongated; those of the wineberry, raspberry, loganberry, and cloudberry are more nearly isodiametric. Thin-walled kinky *hairs* characterize the raspberry and the wineberry, thicker-walled, somewhat kinky or sinuous hairs the loganberry, very thick-walled, stiff hairs the cloudberry.

Mesocarp.—A characteristic of the group is the radial elongation of the cells forming the bulk of the fruit flesh, the increase in size of the fruit during growth, as shown by Tschierske,[1] being due to the increase in length of these cells and not to cell division.

Endocarp.—As in the drupes, the tissue is sclerenchymatous, but typical stone cells are absent, all the cells being fibers which are longitudinally arranged in the outer part and transversely in the inner, except in the cloudberry where the reverse is true.

Spermoderm.—In the raspberry and loganberry the cells of the *outer epiderm* are larger than those of the *inner epiderm*; in the blackberry, dewberry, and wineberry the reverse is true. A loose tissue occurs between the epiderms of these species. In the cloudberry the cells of all the layers except the outer epiderm are collapsed.

The **Perisperm** forms a thin collapsed tissue.

Endosperm.—Several layers of *aleurone cells* are present.

Embryo.—Small aleurone grains and fat are the visible cell contents.

COMPARATIVE CHEMICAL COMPOSITION.—The saccharine matter is largely reducing sugars. The acids in the principal members of the group are chiefly citric, with small amounts of malic. Such examinations as have been made show that the oil of the seed has a high iodine number.

RED RASPBERRY

Rubus strigosus Michx. = *R. idæus* var. *strigosus* Maxim; *R. idæus* L.

Fr. Framboise. Sp. Frambuesa. It. Lampone. Ger. Himbeere.

As is also true of strawberries and gooseberries, varieties of red raspberries commonly grown in North America have a different parentage from European varieties. In the instance at hand, however, the American species *R. strigosus*, from which most of the American varieties, including the Cuthbert and Marlboro, have been derived, is so closely related to the European species *R. idæus* as to lead some authorities to the conclusion that it is merely a variety of the latter. In addition to the common varieties that yield but one crop, so-called ever-bearing varieties, producing a second crop in the Fall, have been introduced. This is a characteristic of the European species. Yellow-fruited varieties are partly derived from the red and partly from the black species.

The flavor of the berries is less injured by cooking than that of most fruit, which explains the large demand for raspberry jam and soda-water syrup.

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[1] Z. Naturwiss. 1886, **59**, 612.

MACROSCOPIC STRUCTURE.—All the garden varieties have white *flowers* in striking contrast to the large rose-colored flowers of the wild *R. odoratus* L. which also yields edible berries, although seldom gathered. The calyx is five-parted, persistent; the five petals are small, deciduous. The numerous stamens are inserted at the base of the receptacle on which the numerous pistils are borne. Two pendulous ovules are present in each one-celled ovary, one usually becoming abortive. The style is nearly terminal.

On separation from the receptacle at full maturity, the *drupelets* remain together as thimble-like groups (Fig. 217, I). Although there is no organic connection between the individuals, Tschierske[1] has shown that they are closely fitted together like the stones of a vaulted ceiling and held in place by the interlocking of the kinky hairs which are present only on the exposed surface, the facets between the drupelets being smooth.

Each *drupelet* resembles a miniature peach, not only in being hairy but also in having an elongated, furrowed stone (Fig. 217, III and IV). A cross section of the drupelet (II), examined with low magnification, shows that the outer part (F) of the stone is of different texture from the inner (F^1) and that

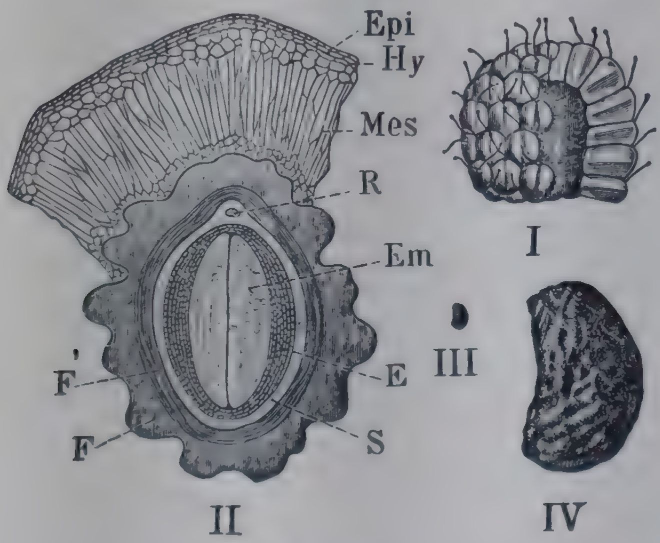

FIG. 217.

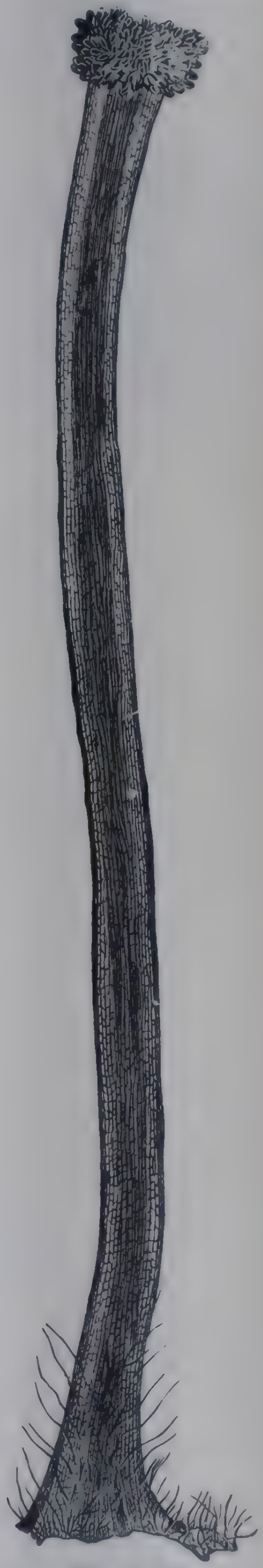

FIG. 218.

FIG. 217.—Red Raspberry. I aggregate fruit. × 1. II drupelet in cross section. *Epi* epicarp; *Hy* hypoderm; *Mes* mesocarp; F outer and F' inner endocarp; S spermoderm; R raphe; E endosperm; *Em* embryo. × 32. III stone. × 1. IV stone. × 8. (A.L.W.)

FIG. 218.—Red Raspberry. Style and stigma. × 32. (A.L.W.)

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[1] Z. Naturwiss. 1886, **59**, 612.

the endosperm (*E*) forms nearly if not quite as much of the bulk of the seed as the cotyledons (*Em*).

The *style* (Fig. 218) on the fruit reaches 4 mm. in length. It is further unlike the style of the strawberry in that at the base it is broad, not constricted, and hairy.

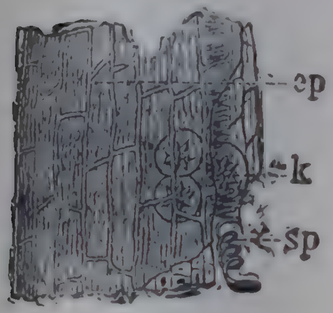

FIG. 219.—Red Raspberry. Style in surface view. *ep* epiderm; *sp* spiral vessel; *k* crystal cells. × 300. (A.L.W.)

MICROSCOPIC STRUCTURE.—As shown by Winton,[1] the work of Tschierske[2] and Marpmann[3] on the European red raspberry applies also to the American berry.

Style (Fig. 219).—Characteristic of the styles are the *epidermal* wrinkles brought out by treating with iodine in potassium iodide (Tschierske) or bleaching with Labarraque solution and staining with safranin. Because of these wrinkles the style is less transparent than that of the strawberry and blackberry.

Pericarp.—The layers are (1) *epicarp* (Fig. 220) made up on the facets of only polygonal cells, on the exposed surface of polygonal cells, hairs (*h*, *h'*), and stomata (*sto*); (2) *hypoderm* (Fig. 217, *Hy*) of collenchyma cells; (3) *mesocarp* (*Mes*), except for the extreme and inner parts of narrow, radially much-elongated cells; and (4) *endocarp* (Fig. 221, *End*) of outer longitudinal (*lf*) and inner transverse (*qf*) sclerenchyma fibers.

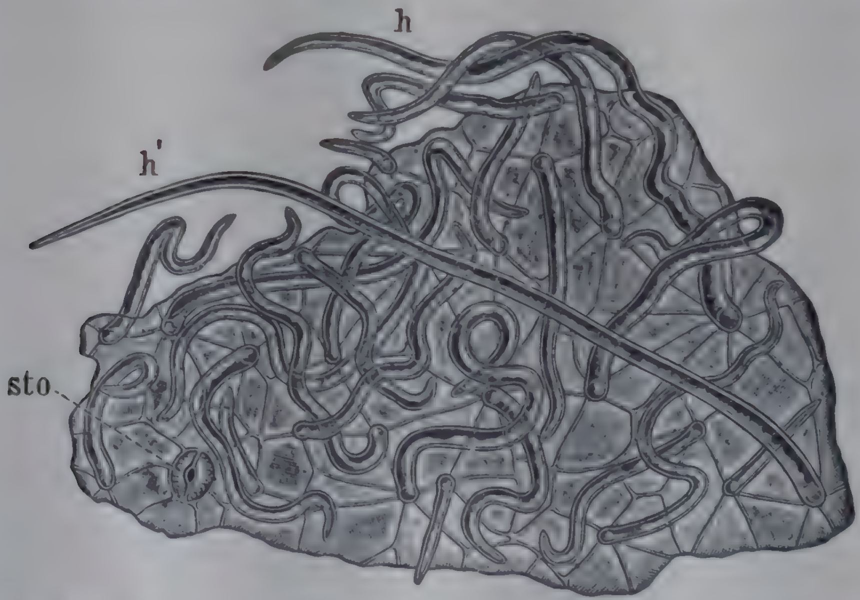

FIG. 220.—Red Raspberry. Epicarp in surface view with *h'* straight hair, *h* sinuous hairs, and *sto* stoma. × 160. (A.L.W.)

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[1] Z. Unters. Nahr.-Genussm. 1902, **5**, 785; Connecticut Agr. Exp. Sta. Rep. 1902, p. 288.

[2] Z. Naturwiss. 1886, **59**, 612.

[3] Z. angew. Mik. 1896, **2**, 102.

For the most part, the epidermal *hairs* (Fig. 220) are thin-walled and kinky (*h*) but occasionally a somewhat thicker-walled straight hair (*h′*) is present. They are so numerous that they often occur at several angles of a parenchyma cell. Tschierske notes that evaporation is retarded by the collenchyma of the *hypoderm*. Cells containing crystals occur among the isodiametric forms of the outer *mesocarp*. Tschierske found in his developmental studies that the increase in size of the fruit on ripening is due to the radial extension of the middle mesocarp cells and not, as in the strawberry, to the sarkogen layer.

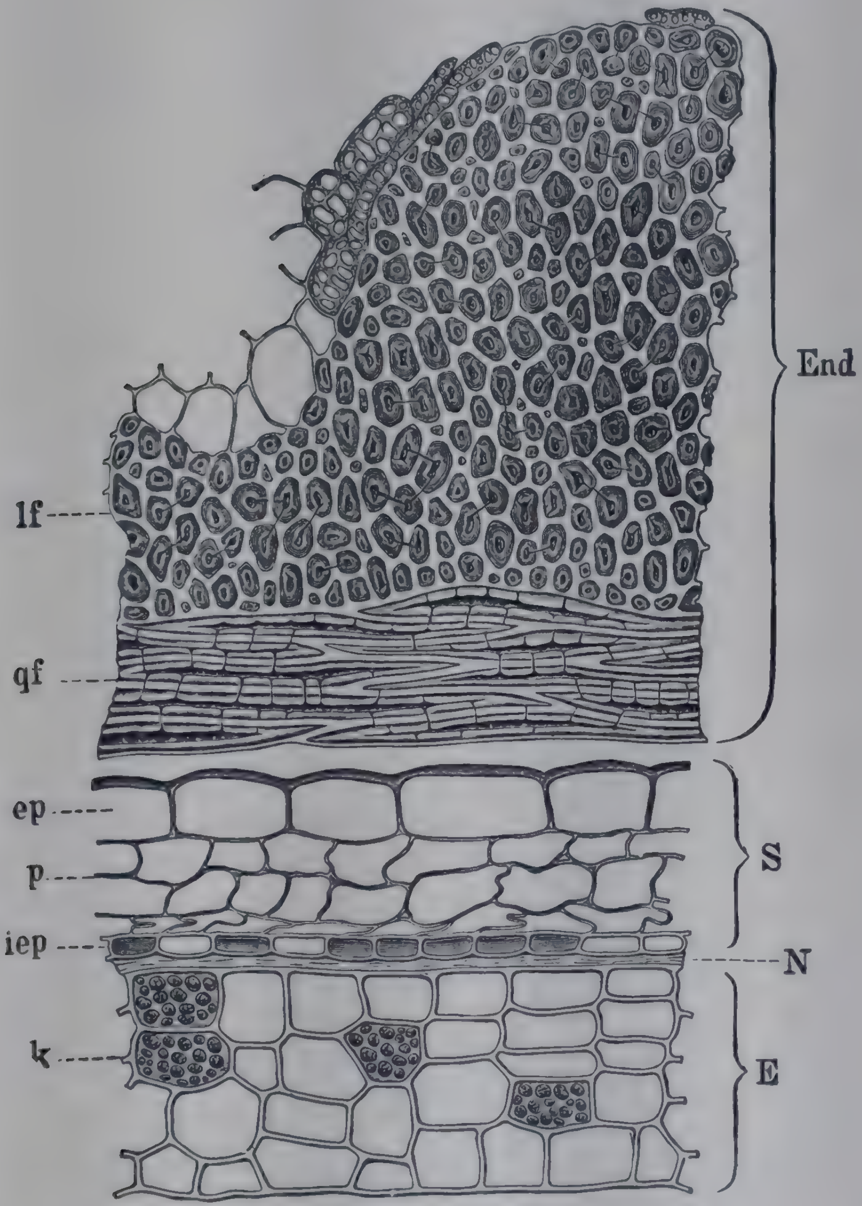

FIG. 221.—Red Raspberry. Stone in cross section. *End* endocarp: *lf* longitudinal fibers, *qf* transverse fibers. *S* spermoderm: *ep* outer epiderm, *p* parenchyma, *iep* inner epiderm. *N* perisperm. *E* endosperm with *k* aleurone grains. × 300. (A.L.W.)

The structure of the *sclerenchyma fibers* of the endocarp resembles that of bast fibers. The middle lamella is faint or not evident while the secondary thickening forms a prominent network in sections, staining yellow with chlorzinc iodine, and the tertiary thickening adjoins the lumen, staining blue.

Spermoderm (Fig. 221, *S*).—Except for the absence of sclerenchyma cells, the structure is similar to that of the drupes, consisting of (1) *outer epiderm* (*ep*) of cuticularized cells, up to 70 μ in diameter, which are quadrilateral in cross section and polygonal in surface view; (2) *parenchyma* (*p*) often collapsed; and (3) *inner epiderm* (*iep*) of cells like those of the outer epiderm but smaller, up to 30 μ, and with brown contents.

Perisperm (Fig. 221, *N*).—Compressed cells.

Endosperm (Fig. 221, *E*).—This consists of *aleurone cells*, several thick, and an inner layer of *compressed cells.*

Embryo.—Small *aleurone grains* and *fat* are the visible cell contents.

CHIEF STRUCTURAL CHARACTERS.—Berries thimble-shaped; drupelets red or yellow, hairy on exposed surface; style 4 mm., at base hairy and broadened; stone furrowed. Spermoderm thin; endosperm nearly as bulky as embryo.

Epicarp hairs mostly thin-walled, kinky; mesocarp cells radially much elongated; endocarp fibers longitudinally elongated in outer and transversely in inner part. Outer epidermal cells of spermoderm larger than inner.

CHEMICAL COMPOSITION.—On the next page are summaries of analyses by Munson, Tolman, and Howard[1] of both red and black raspberries grown in the United States and of analyses by Olig[2] of raspberries, varieties not stated, grown in Germany and Holland.

Analyses by Hotter[3] of the pulp of 6 samples grown in Austria, not strictly comparable with those in the foregoing table, gave as follows: total solids 13.3 to 30.5, insoluble solids 4.0 to 16.3, extract 9.4 to 14.1, total sugars as invert 4.9 to 6.6, dextrose 2.1 to 3.3, levulose 2.5 to 3.4, sucrose 0.2 to 0.3, acids as malic 1.6 to 2.3, tannin 0.21 to 0.31, total ash 0.44 to 0.78, and phosphoric acid 0.07 to 0.16 per cent.

Results of determinations of protein, acidity, reducing sugars, and soluble pectins, made by Knight,[4] on raspberries grown under like conditions show wide variation but no correlation with canning, cooking, or dessert qualities.

The formation of volatile substances in raspberries during ripening, according to Rendle,[5] takes place without the aid of microorganisms.

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[1] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **66** rev.

[2] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

[3] Z. landw. Versuchsw. 1906, **9**, 747.

[4] Univ. Bristol Agr. Hort. Res. Sta. Ann. Rep. 1932, p. 32.

[5] Analyst 1933, **58**, 69.

Composition of Raspberries

	Samples	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, reducing	Sucrose	Alcohol ppt.	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	%	cc.
Munson et al.:										
Red	2									
Min		13.16	6.62	0.93	1.57	3.52	0.76	0.70	0.53	59
Max		13.41	7.12	1.02	1.59	3.53	0.83	0.78	0.55	61
Aver		**13.28**	**6.87**	**0.98**	**1.58**	**3.52**	**0.80**	**0.74**	**0.54**	**60**
Black	2									
Min		18.67	8.59	1.13	1.11	6.39	0.00	....	0.77	76
Max		21.97	11.23	1.30	1.11	6.59	0.00	....	0.85	115
Aver		**20.32**	**9.91**	**1.21**	**1.11**	**6.49**	**0.00**	....	**0.81**	**96**
Olig:										
German	4									
Min		11.90	5.33	....	1.10	2.36	0.10	....	0.56†	44
Max		15.99	7.89	....	2.20	4.44	0.34	....	0.64†	51
Aver		**13.73**	**6.53**	....	**1.84**	**3.53**	**0.18**	....	**0.60**†	**48**
Dutch	4									
Min		13.07	8.71	....	1.63	0.37	0.02	....	0.50‡	37
Max		17.46	13.63	....	1.90	2.29	0.17	....	0.59‡	50
Aver		**14.74**	**10.28**	....	**1.80**	**1.02**	**0.10**	....	**0.55**‡	**44**

* Cc. $N/10$ acid per 100 grams of fruit. † Phosphoric acid, total 0.081 to 0.113, aver. **0.102**%; water-soluble 0.050 to 0.073, aver. **0.061**%. ‡ Phosphoric acid, total 0.093 to 0.128, aver. **0.103**, water-soluble 0.036 to 0.055, aver. **0.046**%.

Owing to the high enzymic activity of this fruit, pectic substances change rapidly after picking with consequent loss of gelatinizing power, but this change is arrested by heating.

Composition of Raspberry Juice.—From the data given above by Munson and co-workers may be derived figures for the composition of the juice agreeing closely with those by analysis (see Strawberry).

Summaries of actual analyses by Windisch and Schmidt[1] of the juice of German red and black raspberries, and by Somogyi and Weiser[2] of the juice of Hungarian berries of unknown varieties, appear in the table on the next page.

Somogyi and Weiser also examined commercial raspberry juice which in Germany and Austria is extensively used in bottled form. In first pressings they found 1.44 to 2.55, aver. **1.99** per cent of alcohol; in second pressings 1.01 to 1.66 aver. **1.35** per cent of alcohol.

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[1] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[2] Ibid. 1916, **32**, 408.

COMPOSITION OF RASPBERRY JUICE
(Grams per 100 cc.)

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
German:										
Red......	19									
Min....		1.032	8.30	0.18	1.16	4.41	....	0.10	0.34	42
Max...		1.047	12.27	0.46	2.20	7.54	....	0.11	0.58	69
Aver...		**1.040**	**10.39**	**0.34**	**1.67**	**6.02**	....	**0.11**	**0.45**	**53**
Black	4									
Min....		1.040	10.48	0.29	1.13	6.37	....	....	0.49	59
Max...		1.055	14.30	0.39	1.57	8.87	....	....	0.66	70
Aver...		**1.047**	**12.17**	**0.36**	**1.38**	**7.51**	....	**0.14**†	**0.55**	**62**
Hungarian:	8									
Min....		1.048	12.53	0.12	1.62	7.27	0.55	....	0.38	50
Max...		1.062	16.02	0.66	2.38	10.50	1.62	....	0.69	94
Aver...		**1.055**	**14.26**	**0.34**	**2.02**	**8.65**	**1.04**	....	**0.49**	**66**

* Cc. $N/10$ acid per 100 grams of juice. † 1 sample.

Composition of Raspberry Seeds.—Krzizan[1] found 14.6 to 18 per cent of oil in the seeds. An analysis by Pritzker and Jungkunz[2] gave water 54 per cent and the following composition of the dry matter: protein 12.2, fat (oil) 16.7, lignin-free fiber 8.6, ash 2.13, and sand 0.11 per cent, also alkalinity number 6.1.

Fatty Oil of Seed. *Physical and Chemical Values.*—Krzizan[1] in the expressed oil and Pritzker and Jungkunz[2] in the extracted oil obtained quite different values as shown in the table below:

VALUES OF RASPBERRY SEED OIL

	Sp. gr. 15° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Acid No.	Phytosterol
							%
Krzizan:							
Min.......	0.9265	186.9	172.3	....	....	2.9	0.73
Max.......	0.9303	192.3	175.9	....	....	40.6	1.10
P. and J.:							
Min.......	0.9202	179.5	117.2	0.55	0.40	....	....
Max.......	0.9238	188.7	159.5	0.55	0.50	....	....

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[1] Z. öffentl. Chem. 1907, **13**, 263; Chem. Rev. Fett-Harz-Ind. 1909, **16**, 1.

[2] Mitt. Lebensm. Hyg. 1930, **21**, 53.

Pritzker and Jungkunz give the following values of the crude fatty acids: pure fatty acids 95.7 to 95.9, solid acids 4.3 to 18.4, liquid acids 81.6 to 95.7, neutralization number of purified acids 153.8 to 198.9, refractive index at 40° C. 1.4569 to 1.4597, average molecular weight 282.2 to 364.7, and neutralization number of solid acids 159.5 to 200.7.

Composition.—Krzizan states that the liquid fatty acids consist chiefly of linolic and linolenic acids with smaller amounts of oleic and iso-linolenic acids.

Respiration.—Gore,[1] working with the Cuthbert, noted a maximum evolution of 311 mg. of carbon dioxide per kilo per hour at 30.8° C. and a minimum of 22 mg. at 2.1° C.

Acids.—Bigelow and Dunbar[2] have compiled the results of 10 investigations, all but 2 of which indicate that the acid is *citric* with little or no other acid. Hempel and Friedrich,[3] however, in different samples found citric and *malic* in different proportions, and Chauvin, Joulin, and Canu[4] only *tartaric*. Bigelow and Dunbar, as a result of their own investigation, conclude that the acid of the red raspberry is probably citric solely and that malic, if present at all, is in traces only. Nelson,[5] by the ester distillation method, corroborates their view, adding that about 97 per cent is citric and about 3 per cent *l*-malic acid. Muttelet[6] found 2.12 per cent of citric acid.

In the black raspberry Nelson found only citric acid.

Mineral Constituents.—A partial analysis of the ash of raspberries by Kulisch[7] gave, on the basis of the fresh fruit: ash 0.611, potash (K_2O) 0.216, lime (CaO) 0.070, magnesia (MgO) 0.053, and phosphoric acid (P_2O_5) 0.105 per cent.

Minor Mineral Constituents. *Iron.*—Berries 6 mg. per kilo, fresh basis (Häusermann).[8] Berries 9.9 mg. per kilo, fresh basis (Peterson and Elvehjem).[9]

Manganese.—Berries 45.9 mg. per kilo, dry basis (Peterson and Skinner).[10]

Copper.—Berries 1.3 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson)[11]

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[1] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[2] J. Ind. Eng. Chem. 1917, **9**, 762.

[3] Z. Unters. Nahr.-Genussm. 1906, **12**, 725.

[4] Mon. sci. 1908, **69**, 449.

[5] J. Am. Chem. Soc. 1925, **47**, 1177.

[6] Ann. fals. 1922, **15**, 453.

[7] Z. angew. Chem. 1894, p. 148.

[8] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[9] J. Biol. Chem. 1928, **78**, 215.

[10] J. Nutrition 1931, **4**, 419.

[11] J. Biol. Chem. 1929, **82**, 465.

BLACK RASPBERRY

Rubus occidentalis L.

Fr. Framboise de Virginie. Ger. Schwarze Himbeere.

Black caps and thimble-berries are other common names for black raspberries derived from native American species. They differ from red raspberries in having smaller drupelets and being of a purple-black color. Distinctions based on the character of the cane, leaf, and flower are of interest chiefly in classification.

Histologically the black varieties agree closely with the red.

CHEMICAL COMPOSITION.—See also Red Raspberry.

Respiration.—Gore,[1] working with 6 samples of the variety Kansas, noted a maximum evolution of 284 mg. of carbon dioxide per kilo per hour at 28.4° C. and a minimum of 25 mg. at 1.9° C.

Minor Mineral Constituents. *Copper.*—Berries 1.4 mg. per kilo fresh basis (Lindow, Elvehjem, and Peterson).[2]

BLACKBERRY

Rubus spp.

Fr. Mûre sauvage. Sp. Zarza. It. Mora del rovo. Ger. Brombeere.

Formerly the common tall blackberry was known as *R. villosus* Ait. and the dewberry or common running blackberry as *R. canadensis* L.; L. H. Bailey,[3] however, after examining types and specimens in European herbariums, has shown that the former Latin name belongs to the dewberry and the latter to a thornless tall blackberry (*R. Millspaughii* Brit.). The name *R. nigrobaccus* Bailey was proposed for the tall blackberry, but this appears to have given place to *R. allegheniensis* Porter. Other American species are mentioned by Bailey [4] as probable parents of cultivated blackberries. The illustrations and descriptions herewith are based on a study of the Snyder, a short cluster, cultivated variety, said to be derived from *R. nigrobaccus* var. *sativus* Bailey. European blackberries, grouped as *R. fruticosus*, which, like American species, are much confused, are not here considered.

Blackberries ripen after raspberries and before Fall fruits. They are in demand for jellies and cordials.

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[1] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[2] J. Biol. Chem. 1929, **82**, 465.

[3] Evolution of our Native Fruits, London, 1898, pp. 366, 379.

[4] Stand. Cycl. Hort., New York, 1922.

MACROSCOPIC STRUCTURE.—The petals of the blackberry *flower* are white, longer than the sepals, and more conspicuous than those of the raspberry. The aggregate *fruits* form either short or long clusters. The black, or in some cultivated varieties yellow, drupelets are firmly attached to the receptacle by a broad base and are picked with it. The *style* (Fig. 222) is broad but only 2 mm. long or only half the length of the raspberry style. It commonly arises from a depression in the drupelet. Drupelets and styles are smooth throughout. The *stones* (Fig. 223) are furrowed as in the raspberry but are larger.

MICROSCOPIC STRUCTURE. Receptacle.—Owing to the breadth of the drupelets at the base, the *epiderm* of the receptacle is reduced to small compass. The bulk of the tissue is *pith parenchyma* with strongly developed *bundles* near the surface.

Style.—Hairs are lacking, also wrinkles on the *epiderm.*

Pericarp (Fig. 224).—The *epicarp* (*epi*) consists of transversely elongated cells and stomata (*sto*). Hairs are absent on American blackberries. The *hypoderm* (*hy*) cells are large and longitudinally elongated. As in the raspberry, the *mesocarp* cells are mostly radially elongated, only those in the very outer and inner parts being isodiametric; some of the cells contain crystal rosettes (*k*). The *endocarp* differs from that of the raspberry only in that there are more rows of fibers.

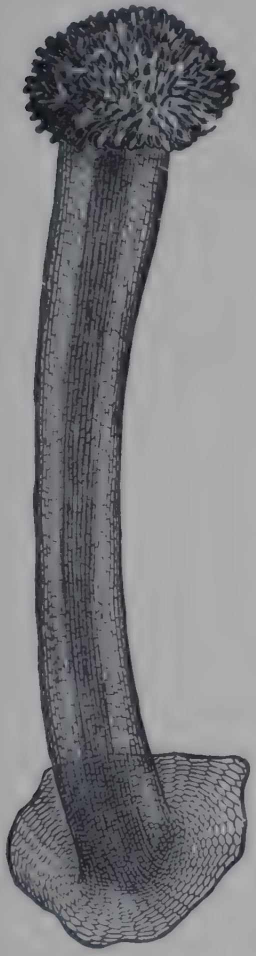

FIG. 222.

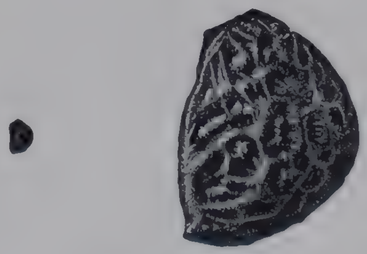

FIG. 223.

FIG. 222.—Blackberry. Style and stigma. × 32. (A.L.W.)
FIG. 223.—Blackberry. Stone. × 1 and × 32. (A.L.W.)

Spermoderm.—Godfrin [1] notes briefly the structure of a blackberry which he calls *R. fruticosus* L.

The structure of the American blackberry here considered differs from that of the raspberry merely in the relative size of the cells of the

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[1] Soc. Sci. Nancy. 1880, p. 153.

outer and *inner epiderm,* the maximum diameter being 40 μ and 60 μ respectively, whereas in the raspberry the cells of the outer epiderm are larger.

Chief Structural Characters.—Receptacle and drupelets firmly united; drupelets smooth, larger than in raspberry; style 2 mm., arising commonly from depression; stones and seed as in raspberry, but larger.

Epicarp cells transversely elongated; hypoderm cells longitudinally elongated; mesocarp and endocarp as in raspberry but more robust. Outer epidermal cells of spermoderm smaller than inner (reverse in raspberry).

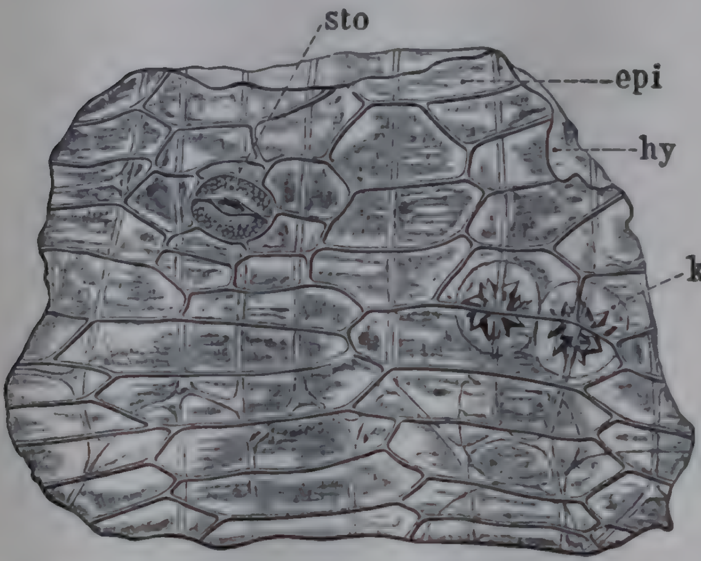

Fig. 224.—Blackberry. Outer pericarp in surface view. *epi* epicarp with *sto* stoma; *hy* hypoderm; *k* crystal cells. × 160. (A.L.W.)

CHEMICAL COMPOSITION—A single analysis by Kulisch [1] of the fruit of European blackberries and a summary of analyses by Munson, Tolman, and Howard [2] of 3 samples of American blackberries are given in the following table:

Composition of Blackberries

	Samples	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, reducing	Sucrose	Alcohol ppt.	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	%	cc.
Kulisch......	1	15.10	....	1.62	1.41	6.46	0.48	....	0.61	..
Munson et al.:	3									
Min.......		12.06	4.72	0.79	0.78	4.57	0.00	0.61	0.45	55
Max.......		13.65	6.24	1.11	1.16	4.74	0.49	0.74	0.82	91
Aver.......		**12.73**	**5.45**	**0.92**	**0.91**	**4.67**	**0.16**	**0.68**	**0.59**	**69**

* Cc. *N*/10 acid per 100 grams of fruit.

Analyses of the pulp of 5 samples of Austrian blackberries by Hotter,[3] on a somewhat different plan from those above, showed: total solids 13.4 to 16.8, insoluble solids 6.0 to 6.4, extract 9.1 to 10.8, total sugars as invert 5.9 to 6.8, dextrose 2.9 to 3.6, levulose 3.1 to 3.2, sucrose 0.4 to 0.6, acids as malic 0.6 to 1.1, tannin 0.21 to 0.36, total ash 0.46 to 0.60, and phosphoric acid 0.06 to 0.09 per cent.

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[1] Z. angew. Chem. 1894, p. 148.

[2] U. S. Dept. Agr., Bur. Chem. 1905, Bul. 66 rev.

[3] Z. landw. Versuchsw. 1906, 9, 747.

Composition of Blackberry Juice.—The average composition of the juice of the fruit analyzed by Munson, Tolman, and Howard [1] may be readily calculated, since the percentage of insoluble solids is given.

A summary of results of direct determinations by Windisch and Schmidt [2] obtained on the juice of European blackberries in terms of grams per 100 cc. is given below:

Composition of German Blackberry Juice (Windisch and Schmidt)

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Min....	4	1.030	8.14	0.27	0.65	4.92	0.00	....	0.39	43
Max....	4	1.046	11.81	0.43	2.05	7.25	0.47	....	0.47	52
Aver....	4	**1.038**	**9.91**	**0.34**	**1.52**	**5.77**	**0.21**	**0.13**†	**0.42**	**47**

* Cc. *N*/10 acid per 100 cc. of juice. † 1 sample.

Respiration.—Gore,[3] operating with the wild blackberry and two consecutive day's runs of a single cultivated variety, noted a maximum evolution of 274 mg. of carbon dioxide per kilo per hour at 29° C. and a minimum of 18 at 1.2° C.

Fatty Oil of Seed.—Krzizan [4] obtained from blackberry seeds 12.6 per cent of a yellowish green drying oil having the following values: specific gravity at 15° C. 0.9256, saponification number 189.5, iodine number 147.8, Reichert-Meissl number 0, Hehner number 96.3, and acid number 2.03. The oil contained liquid fatty acids 91.0, solid fatty acids 4.7, and crude phytosterol 0.83 per cent. The liquid acids consisted of oleic acid 17, linolic acid 80, and linolenic acid 3 per cent.

Acids.—Bigelow and Dunbar [5] state that some samples appear to contain only citric acid, others malic but no citric, and still others neither malic nor citric. Nelson,[6] by the ester distillation method, showed that about five-sixths of the total acids of the fruit examined consisted of optically active *isocitric acid*, and *l-malic acid* was present in moderate amount together with traces of *oxalic*, *succinic*, and *citric acids.*

[1] Loc. cit.

[2] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[3] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[4] Rev. Fett-Harz-Ind. 1908, **15**, 7, 29.

[5] J. Ind. Eng. Chem. 1917, **9**, 762.

[6] J. Am. Chem. Soc. 1925, **47**, 568.

Mineral Constituents.—A partial analysis of the ash of the European garden blackberry by Kulisch[1] gave, on the basis of the fresh fruit: ash 0.608, potash (K_2O) 0.200, lime (CaO) 0.089, magnesia (MgO) 0.053, and phosphoric acid (P_2O_5) 0.069 per cent.

Minor Mineral Constituents. *Iron.*—Berries 10 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Copper.—Berries 1.6 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[3]

DEWBERRY

Rubus procumbens Muhl. = *R. villosus* Ait. and other species.

Running blackberries or dewberries of several species are natives of the United States and from them have been derived in recent years a number of cultivated varieties.

MACROSCOPIC STRUCTURE.—Except to the horticulturist, blackberries and dewberries in the basket are alike in appearance. The running habit of one and the bush habit of the other are the most noticeable characteristics of the plants.

MICROSCOPIC STRUCTURE.—Some of the dewberries are slightly pubescent, otherwise they are not markedly different in microscopic structure from the blackberries.

LOGANBERRY

Although a hybrid, the loganberry has become of such great importance as to merit a separate description. It was produced by Judge J. H. Logan of Santa Cruz, California, the parents being the Red Antwerp, a variety to the European raspberry (*R. idæus* L.), and the native California dewberry (*R. vitifolius* Cham. et Schlecht.). Another hybrid is Burbank's Phenomenal. Large quantities of loganberries are produced in the Pacific Coast states for canning and drying. The flavor is composite, resembling more that of the blackberry because of its rather high acidity.

MACROSCOPIC STRUCTURE.—In form and size of aggregate fruit, individual drupelets, and stones (about 3 mm.), and in the presence of the receptacle in the picked fruit, the berry resembles the long-cluster blackberry, but in color, in the presence of hairs on the exposed part of the drupelet and on the base of the styles, and in the length of the style (4 mm.), it is much like the raspberry. Some of the aggregate berries reach or exceed 4 cm. in length.

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[1] Z. angew. Chem. 1894, p. 148.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Ibid. 1929, **82**, 465.

MICROSCOPIC STRUCTURE.—The tissues of both pericarp and seed resemble closely those of the raspberry but the walls of the epicarp hairs are usually somewhat thicker.

Chief Structural Characters.—Aggregate fruit not detached from the receptacle; color dull red; drupelets hairy as in raspberry; style 4 mm. long; stone reticulated, about 3 mm. Seed as in raspberry.

Epicarp hairs sinuous or kinky as in raspberry but rather thicker-walled. Spermoderm as in raspberry.

CHEMICAL COMPOSITION.—One analysis of the fruit by Colby [1] and one by Daughters,[2] also 6 analyses of the juice of the fruit collected at different dates by Daughters,[3] are given in the following table:

Composition of Loganberry and Juice

	Sp. gr. 25° C.	Solids	Protein	Fat	Acids as citric	Invert sugar	Alcohol ppt.	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	cc.
Berries:									
Colby	......	.....	1.09	....	1.37†	8.00	....	....	..
Daughters	......	20.74	4.55	0.61	1.52	7.15	....	0.57	..
Juice:									
Daughters									
July 10, 1916	1.048‡	10.87	0.73	....	3.08	5.37	0.87	0.58	73
Aug. 8, 1916	1.051‡	9.45	0.74	....	2.20	8.39	0.40	0.42	41
July 18, 1917	1.053	.....	....	....	1.90	8.55	....	....	..
July 25, 1917	1.055	12.84	0.87	....	1.60§	8.80	....	0.50	..
July 28, 1917	1.056	12.49	0.50	....	1.51§	9.06	....	0.45	..
Aug. 7, 1917	1.060	14.74	0.37	....	1.54	8.74	....	0.39	..

* Cc. *N*/10 acid per 100 grams of fruit. † In juice constituting 88% of whole fruit. ‡ 16° C. § Volatile acid 0.05 and 0.03% respectively.

Composition of Pulp.—Analyses by Daughters [4] are tabulated below:

	Water	Solids	Protein	Fat	Acids*	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%	%	%
Moist pulp	70.97	29.03	3.73	3.80	1.37	11.06	8.39	0.70
Dried pulp	.....	.....	12.81	13.09	4.71	38.11	28.89	2.39

* As citric.

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[1] California Agr. Exp. Sta. Rep. 1895, p. 177.

[2] J. Ind. Eng. Chem. 1918, **10**, 30.

[3] Loc. cit. and Ibid. 1917, **9**, 1043.

[4] Loc. cit.

Fatty Oil.—Examination by Daughters[1] of the drying oil extracted from the dried pulp gave: specific gravity at 15.5° C. 0.9260, refractive index at 15.5° C. 1.4811, solidifying point −33° C., iodine number 158.32, and saponification number 179.8.

Acids.—Daughters[1] obtained practically the same results in the determination of acids calculated as citric as in actual determinations of *citric acid.* Traces of *tartaric acid* and 0.03 to 0.05 per cent of volatile acids were also found. Hollingshead[2] found no fixed acid other than citric but detected *formic acid* in 3 samples. Nelson[3] reports, by the ester distillation method, about 96 per cent of the acids as citric and about 4 per cent as *l-malic acid.*

WINEBERRY

Rubus phœnicolasius Maxim.

Although not yet generally cultivated in the United States and seldom found on the market, the wineberry introduced from Japan is a valuable addition to our small fruits. It ripens soon after red raspberries. As grown by the writers, the berry is more acid than either black cap or red raspberry but is of good flavor. The canes are long and willowy and propagate by rooting at the ends. They are densely clothed with sharp but rather weak thorns, also with emergences and hairs like those on the calyx.

MACROSCOPIC STRUCTURE.—The petals are smaller than the pointed calyx lobes. The latter increase in size during ripening, enclosing the berry, but finally recurve, leaving the berry exposed. They are densely clothed with red glandular emergences and slender colorless hairs. During picking of the fruit the fingers become sticky with the resinous secretion of the glands.

In shape, size, and arrangement of drupelets, which readily separate from the receptacle, the wineberry is strikingly like the raspberry, but the drupelets are bright scarlet, smooth, and shiny on the exposed surfaces, and the receptacle is bright orange. About the point of attachment the *drupelets* are downy. The *style* is about 2 mm. long (twice that length in raspberry), broadened at the base (constricted in strawberry), smooth at the base (hairy in raspberry), and does not arise from a depression (distinction from blackberry). The *stone,* consisting of endocarp and seed, is smaller than that of the raspberries.

MICROSCOPIC STRUCTURE.—Literature is lacking.

[1] Loc. cit.

[2] U. S. Dept. Agr. 1919, Bul. **773.**

[3] J. Am. Chem. Soc. 1927, **49,** 1300.

Pericarp.—The structure is like that of the raspberry except that the epicarp on the exposed surface consists of polygonal cells without hairs. *Hairs* are, however, present at the point of attachment, forming the down. These are thread-like, kinky, longer, and thinner-walled than those on the raspberry. As in the latter fruit, *crystal rosettes* of calcium oxalate occur in the *mesocarp*.

Spermoderm.—The structure is more like that of the blackberry than the raspberry, the cells of the *outer epiderm* (up to 55 μ) being much narrower than those of the *inner epiderm* (up to 100 μ). Boiling cross sections with very dilute sodium hydroxide expands the cells and brings out delicate beads in the walls of both epidermal layers.

Endosperm and **Embryo.**—As in red raspberry.

Chief Structural Characters.—Berry bright scarlet; drupelets smooth and lustrous on exposed surface, hairy only at base; styles (2 mm.) shorter than in raspberry, smooth and not constricted at base and not arising from a depression; stones smaller than in raspberry.

Hairs longer and thinner-walled than in raspberry. Spermoderm as in blackberry.

CHEMICAL COMPOSITION.—The only data available are the following by Wittmann:[1] water 75.58, fiber 5.51, and pentosans 1.60 per cent.

CLOUDBERRY

Rubus Chamæmorus L.

Fr. Faux mûrier. Ger. Moltebeere.

Baked-apple berry, yellow berry, and salmon berry are other names for this low, creeping sub-arctic species growing wild in cool peat bogs and high places in Europe and across America. In certain regions it is gathered in enormous quantities; in Newfoundland it is canned under the trade name "Bay-Kapples."

MACROSCOPIC STRUCTURE.—The small herbaceous plant, without prickles, bears simple five-lobed leaves and white *flowers*. A small number of soft drupelets, on a small persistent receptacle, form a flattened compound red or yellow *fruit*. The *stones* are yellow-brown, smooth, and easily crushed between the teeth. Both the drupelets and the stones (5 mm.) are larger than those of the other species. The *style* is about 3.5 mm. long, slightly broadened at the base.

MICROSCOPIC STRUCTURE. Pericarp.—This is made up of (1) *epicarp* of isodiametric, porous cells, stomata, and occasional hairs; (2) *mesocarp* of loose, thin-walled parenchyma and delicate vascular bundles; (3) *outer endocarp*, a number of cells thick, of transversely arranged sclerenchyma fibers; and (4) *inner endocarp*, about half as thick as the outer, of longitudinally arranged fibers.

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[1] Z. landw. Versuchsw. 1901, **4**, 131.

The *hairs*, often 0.5 mm. long, are stiff and thick-walled with a narrow lumen. They taper to a blunt point at both ends.

The *fibers* of the endocarp are arranged contrary to those of the raspberry and blackberry which run longitudinally in the outer and transversely in the inner part.

Spermoderm.—An *outer epiderm* of simple brown cells, reaching 80 μ in diameter, and several rows of *collapsed parenchyma* make up this tissue.

Perisperm.—Cells not evident.

Endosperm.—Several layers of *aleurone cells* and inner empty cells make up this layer.

Embryo.—The large cotyledons consist of typical *aleurone cells.*

CHIEF STRUCTURAL CHARACTERS.—Fruit with few drupelets, stone smooth (rough in raspberry and blackberry). Drupelets and stone largest of the group.

Epicarp cells porous, hairs stiff, blunt with narrow lumen and thick walls; outer endocarp fibers transversely, those of inner endocarp longitudinally arranged (in raspberry and blackberry arrangement reversed). Outer epiderm of spermoderm as in raspberry; other layers collapsed.

IV. DRUPES

(*Pruneæ; Chrysobalaneæ*)

Being derived from a superior ovary, the common or prunus drupes lack the receptacle and crown of withered floral parts characteristic of the pomes and are further distinguished by being one-loculed and one-seeded. They differ from each other less than the pomes since all belong in the genus *Prunus* of the tribe *Pruneæ*. The fruit of the icaco, which belongs in the tribe *Chrysobalaneæ* and the genus *Chrysobalanus*, also is a drupe.

COMPARATIVE MACROSCOPIC STRUCTURE. Flower.—In *Prunus* the style is attached near the tip of the ovary, the ovules are pendulous, and the raphe is ventral; in *Chrysobalanus* the style is attached near the base of the ovary, the ovules are ascending, and the raphe is dorsal. Other morphological details are much the same in the flowers of both tribes.

Fruit.—Both tribes have plum-like fruits similar in their general morphology, with a thin skin or epicarp, hairy in the peach and apricot, a succulent (except in the almond)[1] mesocarp, and a hard endocarp, as well as a thin spermoderm, perisperm, and endosperm and fleshy cotyledons. The chief difference is that the endocarp in *Prunus* splits through two sutures with more or less marked ridges while in *Chrysobalanus* it splits through the five to eight ribs.

Deep furrows and pits occur in the hard stone of the peach and nectarine, and similar ones in the almond but owing to the spongy nature of the outer endocarp the structure is obscured. Numerous fibro-vascular bundles of the mesocarp lie at the bottom of the furrows. The stones of the apricot and plums are merely roughened while those of the cherry are smooth.

COMPARATIVE MICROSCOPIC STRUCTURE.—The icaco differs from the prunus drupes chiefly in that the mesocarp consists of radially elongated cells, the endocarp of sclerenchyma fibers only, and the spermoderm of a characterless tissue without sclerenchyma cells. Being unimportant, it is not considered in the following discussion.

Pericarp.—Among those who have studied the tissues are Lampe,[2]

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[1] Described in Vol. I under Oil Seeds.

[2] Z. Naturwiss. 1886, **59**, 295.

Bordzilowski,[1] Garcin,[2] Micko,[3] and Howard.[4] Four layers or zones are present in all the species: (1) *epicarp*, (2) *hypoderm*, (3) *mesocarp* with fibro-vascular bundles, and (4) *endocarp*.

The *epicarp cells* are large in the cherries (up to 100 μ), medium sized in the European plum (up to 60 μ), small in the Japanese plum (up to 40 μ) and nectarine, and smaller still in the peach and apricot.

The *epicarp* is hairy in the almond, peach, and apricot; smooth or practically so in the nectarine, plums, and cherries. *Peach hairs* have thick walls, narrow lumen, and are so narrowed at the base as to appear pointed; *apricot hairs* have somewhat thinner walls, the lumen equaling or exceeding them in breadth, and a broad, bulbous base; *almond hairs* are intermediate.

All the species have a *mesocarp* of large, sac-like pulp cells, smaller cells, each with an oxalate rosette, and fibro-vascular bundles with spiral, reticulated, and pitted vessels. Accompanying the bundles are *sclerenchyma cells* and *fibers*, the walls of which are thin in the peach, plums, and cherries, thick in the apricot. Crystal fibers—rows of thin-walled cells with crystal rosettes—are adjacent.

Stone cells make up the endocarp or shell of the stone in all the species. These are loosely arranged in the outer part of the almond, especially the paper-shelled variety, but in the other species they form a dense tissue throughout. They are isodiametric or irregular in shape, except toward the inner surface where there is a zone of narrow, transversely elongated forms and also in the case of all the species but the cherries an innermost zone of longitudinally elongated forms.

Spermoderm, Perisperm, Endosperm, and **Embryo.**—See Drupes under Oil Seeds, Volume I.

COMPARATIVE CHEMICAL COMPOSITION.—The *acid* of the plum and cherry appears to be malic and of the apricot and peach both malic and citric. The *Prunus* drupes, according to Reif[5] contain *sorbitol*.

The kernels of the pits, including the almond which is a dry drupe, are non-starchy and oily. The nature of the proteins and fat, also of amygdalin present in certain species, is described in Volume I.

[1] Arb. Kiew. Nat. Ges. 1888, **9**, 65.

[2] Ann. soc. nat. bot. Ser. VII, 1890, **12**, 175.

[3] Z. allg. oesterr. Apoth.-Ver. 1893, **31**, 2, 21.

[4] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **66**.

[5] Z. Unters. Lebensm. 1934, **68**, 179.

PLUM

Prunus domestica L. = *P. communis* Huds.

Fr. Prune. Sp. Ciruela. It. Susina. Ger. Pflaume.

Asia is believed to be the original habitat of the cultivated plum. It was grown by the Greeks and Romans. The common pomological forms are grouped as follows: (1) Damson, Bullace, and probably St. Julien plum (var. *insititia* Bailey), (2) Mirabelle plum (var. *maliformis* L.), (3) green gage or reine-claude (var. *Cereola* L.), and (4) prune (var. *galatensis* Auth.). The cherry plum, now regarded as a separate species (*P. cerasifera* Ehrh.), was classed by Linnæus as *P. domestica* var. *Myrobalan*. A number of American species of *Prunus* described by Sargent[1] and Bailey[2] yield small yellow or red (not blue-black) edible plums.

Whole plums are eaten out of hand, dried, and canned. From them are made jam, with or without the removal of the stones, and a remarkably stiff jelly. Dried prunes are perhaps the most widely known of dried temperate fruits other than raisins.

MACROSCOPIC STRUCTURE.—Such characters as are the same for all drupes of the tribe *Pruneæ* are described in the introductory section. From the peach, the plum is distinguished by the absence of hairs on the epicarp and of deep wrinkles and pits in the stone; from the apricot, by the entire absence of hairs. The nectarine also has a smooth skin but the stone is like that of the peach, of which it is a variety.

The *fruit* is ovoid or nearly spherical, varying from the size of a large cherry to several centimeters long. There are blue-black, red, yellow, and green varieties, the color of the flesh varying from white or green to orange. The *stone* is flattened, elongated, only slightly roughened on the surface, with a narrow groove in the dorsal suture and two longitudinal ridges flanking the ventral suture. The endocarp is hard and compact but thin, often not more than 1 mm. thick. On cracking, it tends to split through the ventral suture.

The *seed* varies from broad to narrow but is more or less pointed at the end, in which is the small radicle.

MICROSCOPIC STRUCTURE.—References to the more important literature are given under the head Drupes above.

Pericarp.—The structure is quite simple. The four layers are (1)

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[1] Manual Trees of North America, Boston, 1905, pp. 509 to 520.

[2] Stand. Cycl. Hort., New York, 1922, under *Prunus*.

epicarp (Fig. 225) of polygonal, often beaded cells, up to about 60 μ, containing the coloring matter that characterizes the fruit, also stomata; (2) *hypoderm* of several layers of isodiametric, thickened cells; (3) *mesocarp* of large sac-shaped cells, often containing stellate groups of needle crystals, also smaller cells each containing an oxalate rosette and fibro-vascular bundles accompanied by thin-walled sclerenchyma fibers; and (4) *endocarp* of stone cells with colorless walls and contents.

The division of the *epicarp* cells into daughter cells is often marked. Red and blue coloring matter is present in solution, green as chlorophyl grains.

Spiral, reticulated, and pitted vessels, also crystal fibers, are present in the *fibro-vascular bundles* of the mesocarp. Accompanying the bundles, in addition to the thin-walled sclerenchyma fibers, are parenchyma cells containing masses of strongly refractive material which take on the coloring matter from the epicarp on cooking.

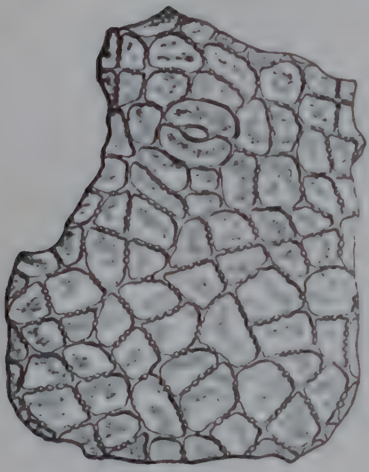

FIG. 225. — European Plum. Epicarp in surface view. × 160. (K.B.W.)

The *stone cells* of the endocarp are for the most part of considerable size, either isodiametric or somewhat elongated. Toward the inner surface they become narrow and transversely elongated, forming a zone about 100 μ thick, abutting against an inner zone, about 150 μ thick, of narrow, longitudinally elongated forms.

Spermoderm, Perisperm, Endosperm, and **Embryo.**—See Plum Kernel, Volume I.

CHIEF STRUCTURAL CHARACTERS.—Fruit ovoid, blue-black, red, yellow, or green. Epicarp smooth; stone (endocarp) slightly roughened, hard but thin. Seed small (about 1.5 cm.), flattened, pointed, broad or narrow.

Epicarp of beaded, polygonal cells and stomata; mesocarp of large sac-shaped cells and occasional small ones with rosette crystals; bundles accompanied by thin-walled, elongated sclerenchyma fibers; endocarp of large isodiametric stone cells and inner zones of elongated stone cells.

CHEMICAL COMPOSITION.—Proximate analyses of 12 samples of prunes grown in California were made by Colby and Dyer.[1] The varieties represented were Prune d'Agen, French, Wangenheim, Robe de Sergent, Fellenberg, Hungarian, Bulgarian, German, Datte d'Hongrie, and St. Catherine. A summary is given in the table on the next page.

Colby,[2] in continuation of the work, analyzed 9 additional samples of prunes, making the total 21 of which 12 were French varieties, also

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[1] California Agr. Exp. Sta. Rep. 1891/2, p. 92; 1892, Bul. **97**.

[2] Ibid. Rep. 1893/4, pp. 257 and 268.

COMPOSITION OF PRUNES (COLBY AND DYER)

	Weight	Flesh	Pits	Water	Protein	Ash	Juice*	Marc*	Acids†	Sugars†	Protein‡
	g.	%	%	%	%	%	%	%	%	%	%
Min...	10.0	92.5	3.7	75.96	0.76	0.33	53.0	13.2	0.24	12.05	2.06
Max..	80.5	96.3	7.5	85.69	1.16	0.61	86.8	47.0	0.95	25.60	5.44
Aver..	**27.1**	**94.5**	**5.5**	**81.29**	**0.93**	**0.40**	**73.3**	**26.7**	**0.43**	**16.70**	**3.94**

* Per cent in flesh. † Per cent in juice. ‡ Per cent in pits.

3 varieties of plums, namely Coe, Golden Drop, and Yellow Egg. These later analyses did not extend the range beyond that of the earlier analyses, except that the sugar content in one long-ripened sample was somewhat higher. The average analyses of the pulp (fruit flesh) of the prunes and plums were respectively as follows: protein 0.99 and 0.84, sugars 16.11 and 13.25, and ash 0.47 and 0.52 per cent. The pulp made up 94.2 and 95.2 per cent of the whole fruit which contained water 77.38 and 77.43 and organic matter 22.13 and 22.04 per cent.

In analyses by Shaw[1] the average sugar content of the juice of Oregon prunes (17.52 per cent) was about 2.5 per cent less than the average of that of California prunes, while the protein (1.32 per cent) of the edible portion was higher. Later analyses[2] of 3 varieties gave results summarized in the table which follows:

COMPOSITION OF OREGON PRUNES (SHAW)
(Results in per cent of flesh)

	Aver. weight	Flesh*	Pits*	Juice	Marc	Water	Protein	Acids	Sugars	Ash
	g.	%	%	%	%	%	%	%	%	%
Petite:										
Min...	15.8	92.0	1.9	73.5	10.0	67.49	0.81	0.12	8.75	0.45
Max...	30.5	98.2	8.0	90.0	30.0	83.41	1.66	0.65	18.68	1.59
Aver..	**22.2**	**94.3**	**5.7**	**78.6**	**21.4**	**72.26**	**1.14**	**0.35**	**13.89**	**0.76**
Italian:										
Min...	25.3	92.3	2.7	61.0	9.0	69.92	0.87	0.22	8.52	0.79
Max..	36.6	97.3	7.7	91.0	39.0	83.55	1.33	0.92	14.04	1.63
Aver..	**29.8**	**94.4**	**5.6**	**76.4**	**23.6**	**77.07**	**1.09**	**0.42**	**11.56**	**0.94**
Silver:										
Min...	23.0	91.3	4.7	63.2	11.0	69.91	0.87	0.18	10.26	0.57
Max..	61.5	95.3	8.7	89.0	36.8	81.43	1.70	0.65	16.67	1.07
Aver..	**43.9**	**93.5**	**6.5**	**79.5**	**20.5**	**76.61**	**1.26**	**0.32**	**14.06**	**0.77**

* In whole fruit.

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[1] Oregon Agr. Exp. Sta. 1897, **45**, 91.

[2] Ibid. 1900, Bul. **61**.

Analyses by Kulisch[1] of the pulp (fruit flesh) of 3 types of plums presumably grown in Germany and by Feruglio and Bernardis[2] of the flesh of plums grown in the vicinity of Friuli and Gorizia, Italy, are given below. The Italian fruit was made up of flesh plus skin 95.18, shell of pits 3.53, and kernels of pits (including skin) 1.29 per cent. The juice contained 0.39 to 0.46 per cent of acid, calculated as malic, and the water-free kernels of the pits 24.81 to 26.81 per cent of protein and 42.61 to 45.69 per cent of fat.

COMPOSITION OF PLUM PULP

	Water	Protein	Fat	Acids*	Sugars, reducing	Sucrose	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Kulisch:									
Prune......	83.40	0.64	....	1.04	9.42	2.67	....	....	0.32
Green Gage..	85.10	0.75	....	1.29	5.54	4.81	....	....	0.43
Yellow Plum.	84.30	0.79	....	0.60	6.97	4.65	....	....	0.39
F. and B.:									
Min.........	83.00	0.50	0.11	....	4.08	5.41	0.61	0.36	0.34
Max.........	84.00	0.57	0.13	....	4.67	6.20	0.64	0.46	0.45

* As malic.

Detailed analyses of the pulped flesh of 8 samples of plum, 4 each of blue plum and green gage, and 1 of sloe, all grown in Austria, are given by Hotter[3] as follows:

COMPOSITION OF PLUM PULP (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Plum:										
Min.......	12.4	1.6	11.9	0.6	6.5	3.4	2.9	0.7	0.07	0.37
Max......	22.8	2.9	21.3	1.7	13.7	7.6	6.1	4.8	0.20	0.60
Blue Plum:										
Min.......	15.2	1.9	12.1	0.4	5.6	2.9	2.7	2.0	0.05	0.40
Max.......	18.1	3.2	16.5	1.0	10.6	6.5	4.1	3.9	0.09	0.54
Green Gage:.										
Min.......	15.0	2.2	14.2	0.7	7.7	4.7	2.9	0.6	0.10	0.51
Max......	20.5	3.2	18.3	1.7	11.3	6.2	5.1	5.1	0.24	0.69
Sloe.........	26.1	9.6	15.7	0.8	6.7	3.5	3.1	...	0.11	1.27

* As invert. † Phosphoric acid: plum 0.04 to 0.06; blue plum 0.04 to 0.06; green gage 0.04 to 0.08; sloe 0.07%.

[1] Z. angew. Chem. 1894, p. 148.

[3] Z. landw. Versuchsw. 1906, **9**, 747.

[2] Bol. ass. agr. friulana 1916, **31**, 56.

Somewhat different constituents of the flesh were determined by Olig[1] as shown by the average results given below:

	Samples	Solids, sol.	Solids, insol.	Acids as malic	Sugars, reducing	Sucrose	Ash, total	Ash, sol.	Ash, alk.*	P_2O_5 total	P_2O_5 sol.
		%	%	%	%	%	%	%	cc.	%	%
Plums.......	4	10.91	1.79	1.50	9.60	0.11	0.45	0.43	4.68	0.048	0.043
Green Gages.	2	13.92	1.82	1.20	7.98	....	0.56	0.54	6.00	0.061	0.052
Damsons....	2	12.31	1.62	1.01	8.42	0.11	0.43	0.41	4.62	0.049	0.041

* Cc. normal acid per 100 grams of fruit.

Composition of Plum Juice.—Kulisch[2] analyzed the juice of 3 varieties including so-called *Zwetschen*, here given as "plum," and Windisch and Schmidt[3] analyzed 1 variety.

COMPOSITION OF PLUM JUICE

(Grams per 100 cc. juice)

	Samples	Sp. gr. 17.5° C.	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Ash, total	Ash, alk.*
Kulisch:									
Plum........	1	1.075	.....	....	0.89	7.40	5.50	....	..
Green Gage..	1	1.057	.....	....	0.54	3.02	6.66	....	..
Mirabelle.....	1	1.079	.....	....	0.76	6.53	6.98	....	..
W. and S.:									
Mirabelle.....	1	1.072	18.71	0.70	0.61	8.05	4.20	0.65	66

* Cc. *N*/10 acid per 100 cc. juice.

Composition of Dried Prunes.—A range of 35.2 to 53.0 per cent of sugar was found by Colby[4] in 7 samples of California prunes.

Atwater and Bryant[5] have compiled the following summary of 15 analyses: water 16.9 to 27.5, aver. **22.3**; protein 1.4 to 3.2, aver. **2.1**; nitrogen-free extract and fiber 68.1, to 78.6 aver. **73.3**; and ash 1.5 to 3.0, aver. **2.3** per cent.

The average composition of dried prunes from the Santa Clara, Sacramento, and San Joaquin Valleys, as determined by Gale and

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[1] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

[2] Landw. Jahrb. 1892, **21**, 427.

[3] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[4] California Agr. Exp. Sta. Rep. 1894/5, p. 177.

[5] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

Cruess,[1] follows: pits 14.75, water 18.36, solids 77.97, protein 2.79, total sugars as invert 46.78, sucrose 3.37, invert sugar 43.93, total acids as citric 1.20, and ash 2.19 per cent.

Canned Prunes.—Kohman and Sanborn,[2] in attempting to combine the advantages of the improved flavor of French or Santa Clara prunes resulting from drying and the convenience of the fruit canned in syrup, encountered the serious obstacle of can corrosion. By adding citric acid or lemon juice, the corrosion was obviated and the flavor further improved.

Composition of Kernel.—See Plum Kernel, Volume I.

Changes in Composition During Ripening.—Shaw [3] found 19.18 per cent of sugar in the edible portion of unripe fruit and 25.6 per cent in that of the ripe fruit.

Maturity of Italian prunes, as noted by Tucker and Verner,[4] is characterized by softening of the flesh, development of pigment, increase in sugars, and decrease in acidity.

Respiration.—Gore,[5] working with 3 varieties of plums, noted a maximum evolution of 103 mg. of carbon dioxide per kilo per hour at 30.7° C. and a minimum of 5 mg. at 1.3° C.

Acids.—Truchon and Martin-Claude [6] found a trace of *tartaric acid* in green gage plums; Chauvin, Joulin, and Canu [7] found only *citric acid.* Bigelow and Dunbar [8] review the work of earlier investigators and report results of Fitzgerald, of Johnson, and of Pratt, all of the Bureau of Chemistry, on several European and Japanese varieties showing 0.55 to 2.15 per cent of acids by titration, calculated as malic, and practically the same amounts of *malic acid* by the uranyl acetate method. Mutellet [9] reports malic acid as the sole acid, namely: in green gages 1.05, in mirabelles 0.29, and in large plums (Zwetschen) 0.84 per cent.

Determinations by Radin [10] on commercial prunes, presumably dried, showed 0.05 per cent of *benzoic acid.*

Mineral Constituents.—As reported by Colby and Dyer [11] the ash content of the fruit flesh pulp of a sample of French prunes containing 77 per cent of water was 0.434 per cent, of the pits 0.582 per cent, and of the whole fruit 0.442 per cent. Ash analyses gave as shown below:

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[1] Fruit Prod. J. 1931, **10**, 302.

[2] Ind. Eng. Chem. 1933, **25**, 920.

[3] Loc. cit.

[4] Idaho Agr. Exp. Sta. 1932, Bul. **196**.

[5] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[6] Ann. chim. anal. 1901, **6**, 85.

[7] Mon. sci. 1908, **69**, 449.

[8] J. Ind. Eng. Chem. 1917, **9**, 762.

[9] Ann. fals. 1922, **15**, 453.

[10] J. Ind. Eng. Chem. 1914, **6**, 518.

[11] Loc. cit.

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Flesh...	69.50	3.07	3.01	5.33	0.83	0.17	11.56	2.13	4.30	0.20
Pits....	24.01	4.53	6.04	16.26	1.14	1.90	32.98	5.40	7.88	0.22
Whole..	65.92	3.18	3.24	6.16	0.85	0.31	13.19	2.37	4.56	0.19

Minor Mineral Constituents. *Iron.*—Edible portion 6 mg. per kilo, fresh basis (Häusermann).[1] Dried prunes 29 mg. per kilo, as sold (Sherman).[1] Plums 7.7 mg. per kilo, fresh basis; dried prunes 51.7 mg. per kilo, as sold (Peterson and Elvehjem).[2] Stoned prunes 30 to 60 mg. per kilo, calculated to 20 per cent water content (Saywell, Dietz, and Robertson).[3] Dried prunes, 2 samples 21.9, 46.5 mg. per kilo, as sold (Toscani and Reznikoff).[4]

Manganese.—Plums 6.2 mg. per kilo, fresh basis (Peterson and Skinner).[5] Stoned prunes 3 to 6 mg. per kilo, calculated to 20 per cent water content (Saywell, Dietz, and Robertson).[3]

Copper.—Fresh prunes: pulp 9, whole stone 8.5, kernel 19, shell 5.5 mg. per kilo, dry basis (Maquenne and Demoussy).[6] Edible portion: blue plums 1.5 mg. per kilo, fresh basis, dried prunes 4.1 mg. per kilo, as sold (Lindow, Elvehjem, and Peterson).[7] Stoned prunes 2 to 4 mg. per kilo, calculated to 20 per cent water content (Saywell, Dietz, and Robertson).[3]

Zinc.—Edible portion 0.3 mg. per kilo, fresh basis (Bertrand and Benzon).[8]

AMERICAN PLUMS

Prunus spp.

A number of American species of *Prunus* described by Sargent[9] and Bailey[10] yield small yellow or red (not blue-black) edible plums. Some of these are parents of cultivated varieties.

[1] Sherman: U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] J. Ass. Off. Agr. Chem. 1934, **17**, 290.

[4] J. Nutrition 1934, **7**, 79.

[5] Ibid. 1931, **4**, 419.

[6] Compt. rend. 1920, **170**, 87.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

[9] Manual Trees of North America, Boston, 1905, pp. 509–520.

[10] Stand. Cycl. Hort., New York, 1922, under *Prunus*.

JAPANESE PLUM

Prunus salicina Lindl. = *P. triflora* Roxb.

Fr. Prune de Chine.

This species is said to have originated in China but is extensively grown in Japan where numerous varieties have been developed. Varieties introduced from Japan and others derived from Japanese parents are successfuly grown in the United States, the Abundance and Burbank being especially popular. Bailey, in bulletins of the Cornell Experiment Station, discusses the introduction and development of this type.

MACROSCOPIC STRUCTURE.—The distinctive characters are mostly in parts other than the fruit. Suffice it to say that the *fruit* is red or yellow and does not run into blue or purple strains.

MICROSCOPIC STRUCTURE.—The only distinction between the Japanese and the European plum that has been noted is the smaller size of the *epicarp* cells of the former which commonly are less than 40 μ in diameter, whereas in the latter they reach 60 μ.

APRICOT

Prunus Armeniaca L. = *Armeniaca vulgaris* Lam.

Fr. Abricot. Sp. Albaricoque. It. Albicocca. Ger. Aprikose.

Although the tree was named with the belief that it originated in Armenia, the researches of Decaisne and also Bretschneider show that it grows wild in China and has grown there for over forty centuries.

The two common types, regarded by some as separate species, are: (1) var. *mandshurica* Maxim. of Manchuria, and (2) var. *Ansu* Maxim. of Japan. The black apricot (*P. dasycarpa* Ehrh.), regarded by Koch as a variety of *P. Armeniaca*, is little known and of little value.

Apricots are grown in the United States chiefly in California where the output, especially of sun-dried and canned fruit, is enormous. The light orange color of the dried fruit is secured by sulphuring before drying. The kernels of the seeds, obtained as a by-product in the canning and drying industry, have been used as a substitute for almonds in pastes and confectionery. See Apricot Kernel, Volume I.

MACROSCOPIC STRUCTURE.—Externally the apricot resembles the peach but is not so hairy; at full maturity, it is described as being smooth or nearly so although under a lens hairs are clearly evident. Commonly the color is yellow or orange but some varieties are red or have a red cheek. The *stone* resembles the plum stone but is larger, broader, and almost lens-shaped, with a pronounced sharp keel along the ventral suture flanked on each side by a sharp ridge. Cross sections show that the endocarp forming the shell of the stone is thinner than the endocarp of the peach. The *seed* is about as broad as long, rounded or heart-shaped. It has a somewhat bitter taste.

MICROSCOPIC STRUCTURE. Pericarp (Fig. 226).—The structure differs from that of the plum in that: (1) hairs occur on the *epicarp* (absent in the plum), and (2) the sclerenchyma fibers accompanying the fibro-vascular bundles are thick-walled (usually thin-walled in the plum).

The *hairs* (*t*) on the *epicarp* (*epi*) differ from those of the peach in that they are broad and flask-shaped at the base, and the walls, although thick, are commonly narrower than the lumen. In the peach the hairs are narrower at the base and the walls are usually broader than the lumen.

Some of the *sclerenchyma fibers* (*f*) are broad, others narrow. Broad forms do not commonly occur in either the plum or the peach.

Spermoderm, Perisperm, Endosperm, and **Embryo.**—See Apricot Kernel, Volume I.

Chief Structural Characters.—Fruit similar to peach but not so hairy and stone nearly smooth with sharp keel and ridges on ventral edge. Seed larger, broader, and more nearly round or heart-shaped than in plum.

Epicarp hairs broad at base, walls usually narrower than lumen; mesocarp bundles accompanied by thick-walled, often broad sclerenchyma fibers.

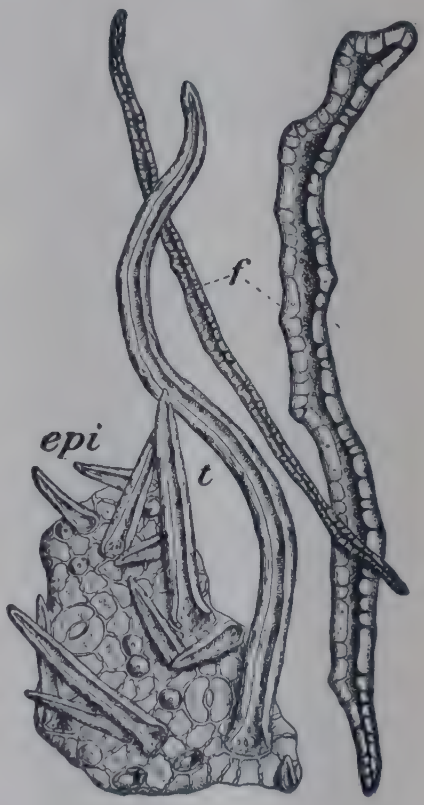

Fig. 226.—Apricot. Surface view of *epi* epicarp with *t* hairs; *f* mesocarp fibers accompanying bundles. × 160. (K.B.W.)

CHEMICAL COMPOSITION.—Five analyses by Colby and Dyer[1] and 7 by Colby,[2] representing 5 varieties, namely Hemskirk, Blenheim, Royal, Peach, and Moorpark, are summarized on the next page.

Kulisch[3] reports pits 9.68 per cent and the following in percentages of the pulp (fruit flesh): water 89.00, protein 0.65, acids as malic 1.23, invert sugar 1.79, sucrose 4.30, and ash 0.519 per cent.

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[1] California Agr. Exp. Sta. Rep. 1891/2, p. 92.

[2] Ibid. 1892/4, p. 257.

[3] Z. angew. Chem. 1894, p. 148.

COMPOSITION OF APRICOTS (COLBY AND DYER)

	Weight	Flesh	Pits	Kernels	Water	Protein	Ash	Juice*	Marc*	Acids†	Sugars†
	g.	%	%	%	%	%	%	%	%	%	%
Min..	41.7	92.9	5.3	1.2	83.76	0.90	0.37	85.3	7.0	0.63‡	11.04
Max..	81.0	94.7	7.1	2.4	86.79	1.64	0.56	93.0	14.7	1.23‡	15.72
Aver..	**62.4**	**93.8**	**6.2**	**1.6**	**85.16**	**1.25**	**0.49**	**90.0**	**10.0**	**0.93‡**	**13.31**

* Per cent in flesh. † Per cent in juice. ‡ As malic.

The range in composition of the pulp of 4 samples grown in Austria, as reported by Hotter,[1] is as follows:

COMPOSITION OF APRICOT PULP (HOTTER)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Sucrose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%	%
Min.....	12.4	2.1	9.1	0.7	5.3	3.2	1.4	1.4	0.06	0.59
Max....	16.7	3.1	15.0	2.2	8.6	4.8	4.2	5.4	0.10	0.86

* As invert. † Phosphoric acid 0.05 to 0.08%.

Olig,[2] in the analysis of 3 samples of apricots, obtained the results, in percentages of the flesh, summarized in the table below:

	Solids, sol.	Solids, insol.	Acids as malic	Sugars, reducing	Sucrose	Ash, total	Ash, sol.	Ash, alk.*	Phos. acid, total	Phos. acid, sol.
	%	%	%	%	%	%	%	cc.	%	%
Min....	8.74	1.56	....	4.04	0.22	0.60	0.57	64	0.051	0.046
Max...	11.46	2.10	....	6.38	3.62	0.80	0.77	82	0.093	0.081
Aver...	**10.47**	**1.79**	**1.55**	**5.01**	**1.42**	**0.72**	**0.67**	**76**	**0.068**	**0.060**

* Cc. *N*/10 acid per 100 grams of fruit.

Composition of Apricot Juice.—Windisch and Schmidt[3] report in grams per 100 cc. of juice results summarized in the following able:

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[1] Z. landw. Versuchsw. 1906, **9**, 747.

[2] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

[3] Ibid. 1909, **17**, 584.

	Sp. gr. 15° C.	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Min.......	1.039	10.11	0.46	0.82	3.77	2.45	0.12	0.50	54
Max.......	1.050	12.97	0.55	0.85	4.20	4.36	0.12	0.52	54
Aver.......	**1.045**	**11.54**	**0.51**	**0.84**	**3.99**	**3.41**	**0.12**	**0.51**	**54**

* Cc. $N/10$ acid per 100 cc. juice.

Composition of Dried Apricots.—Analyses of 2 samples reported by Atwater and Bryant[1] show as follows:

	Water	Protein	Fat	N-f. ext.*	Ash
	%	%	%	%	%
Min.......	26.4	2.9	1.0	62.7	1.4
Max.......	32.4	6.4	1.1	63.3	3.4
Aver.......	**29.4**	**4.7**	**1.0**	**62.5**	**2.4**

* Includes fiber.

Composition of Kernel.—See Apricot Kernel, Volume I.

Acids.—Truchon and Martin-Claude[2] give *tartaric* and *citric* as the acids of the apricot; Kunz and Adam[3] give *citric* and *malic* acids, the former predominating; and Chauvin, Joulin, and Canu[4] give only tartaric acid. Bigelow and Dunbar[5] secured evidence pointing to tartaric or *d*-malic acid but reserved an opinion. Traetta-Mosca, Papocchia, and Galimberti[6] conclude that malic, citric, and tartaric acids are present. Muttelet[7] found malic acid 0.33 and citric acid 1.75 per cent; on the other hand, Nelson,[8] employing the ester distillation method, found *l*-malic and citric acids in dried apricots in the approximate proportion of 25 to 10.

[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Ann. chim. anal. 1901, **6**, 85.

[3] Z. Unters. Nahr.-Genussm. 1906, **12**, 670.

[4] Mon. sci. 1908, **69**, 449.

[5] J. Ind. Eng. Chem. 1917, **9**, 762.

[6] Ann. chim. appl. 1923, **13**, 333.

[7] Ann. fals. 1922, **15**, 453.

[8] J. Am. Chem. Soc. 1924, **46**, 2506.

Colors.—Calculations by Morgen and Madsen,[1] on the basis of chemical and biological data, show a loss of 35 to 41 per cent of *carotene* in drying apricots. Kuhn and Brockmann [2] found in apricots γ-carotene in addition to the common forms and *lycopene.* Brockmann [3] isolated from dried apricots β-carotene in crystalline form and small amounts of lycopene; he also noted indications of γ-carotene. The content of carotene was greater than that in any other fruit examined by him.

Enzymes.—Traetta-Mosca, Papocchia, and Galimberti [4] were unable to find oxidase and peroxidase in either ripe or green apricots. *Invertin, amylase,* and *emulsin* were present in all stages of ripening.

Mineral Constituents.—As reported by Colby and Dyer [5] the ash content of the pulp was 0.542 per cent, of the pits 0.681 per cent, and of the whole fruit 0.550 per cent. Ash analyses by them and by Kulisch [6] appear in the table which follows:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
C. and D.:										
Pulp...	58.89	11.20	3.24	3.31	0.77	0.09	11.20	2.75	8.31	0.58
Pits....	10.95	3.45	6.75	11.58	12.39	1.65	43.76	5.38	2.58	0.65
Whole..	54.88	10.57	3.52	3.85	1.71	0.31	13.86	2.95	7.85	0.60
Kulisch:										
Pulp...	40.0	.....	5.6	3.8	....	....	8.4	....	....	....

Minor Mineral Constituents. *Iron.*—Dried stoned fruit 72.6 mg. per kilo, as sold (Peterson and Elvehjem).[7] Dried stoned fruit, 2 samples, 64.5, 72.5 mg. per kilo, as sold (Toscani and Reznikoff).[8]

Aluminum.—Fruit 60 mg. per kilo, dry basis (Bertrand and Lévy).[9]

Copper.—Kernel 13 mg. per kilo, dry basis (Maquenne and Demoussy).[10] Dried stoned fruit 3.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[11]

Zinc.—Edible portion 0.4 mg. per kilo, fresh basis (Bertrand and Benzon).[12]

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[1] J. Nutrition 1933, **6**, 83.

[2] Naturwissenschaften 1933, **21**, 44.

[3] Z. physiol. Chem. 1933, **216**, 45.

[4] Loc. cit.

[5] Loc. cit.

[6] Loc. cit.

[7] J. Biol. Chem. 1928, **78**, 215.

[8] J. Nutrition 1934, **7**, 79.

[9] Compt. rend. 1931, **192**, 525.

[10] Ibid. 1920, **170**, 87.

[11] J. Biol. Chem. 1929, **82**, 465.

[12] Bul. soc. hyg. aliment. 1928, **16**, 457.

PEACH

Prunus persica Sieb. et Zucc. = *Amygdalus persica* L. =
Persica vulgaris Mill.

Fr. Pêche. Sp. Melocotón. It. Pesca. Ger. Pfirsich.

Linnæus in naming this species was influenced by the statements of Greek and Latin writers that the tree was brought from Persia. De Candolle, however, finds abundant evidence that China is its original home. The varieties most commonly grown in the northern states of the United States belong to the Persian race. In addition there are the north China (often hybridized with the Persian), south China, Indian (represented by varieties grown in the southern states), and flat races. The flat peaches (var. *platycarpa* Bailey = *Persica platycarpa* Decne.), represented by the Peen-to variety, are often twice as broad as high, while the honey peach, belonging to the south China race, has a distinct beak. Nectarines are varieties of the peach with smooth skin and are separately described. The varieties are commercially classed as freestone and clingstone, and according to the color of the flesh as white and yellow.

As a dessert fruit, the season in the north is much extended by shipments from the south. Enormous quantities are canned and dried, the hairy skin in the former case being often removed by dipping in hot dilute (about 0.75 per cent) lye, then in water.

MACROSCOPIC STRUCTURE.—Characteristic of the *flower* is the peculiar solid pink color. The sepals and petals, five each, and numerous stamens are borne at the top of the cup-shaped receptacle which is free from the single loculed, two-ovuled ovary. The petals differ greatly in size, being large and broad in some varieties, small and narrow in others. Only one of the two ovules commonly develops into a seed.

The *fruit* is velvety hairy, white to deep yellow, often with a deep red cheek, and has white or yellow flesh, more or less tinged with red beneath the skin or about the stone. Deep furrows and pits cover the hard brown endocarp or *stone* which reaches 10 mm. in thickness. On the ventral edge are several prominent but irregular longitudinal ridges obscuring the suture through which the shells may be readily separated by inserting a stout knife. A prominent bundle runs longitudinally through the suture tissues, then passes into the locule and becomes the funiculus on which the seed is suspended. Cross sections cut through the endocarp often show holes. These are due to the furrows extending under the stony mass in places.

MICROSCOPIC STRUCTURE.—Lampe[1] studied the structure and development of the pericarp. Other authors who have studied the fruit and seed are noted under the head of Drupes.

Pericarp (Fig. 227).—The tissues are (1) *epicarp* (*epi*) of polygonal cells, occasional stomata, and numerous thick-walled hairs (*t*) narrowed at the base; (2) *hypoderm* (*hy*) of beaded, polygonal cells with an intercellular space at each angle; (3) *mesocarp* (*mes*) of large sac-like pulp cells with formless contents and rosettes of needle-shaped crystals (cr^2); smaller cells with crystal rosettes of the usual type (cr^1), and fibro-vascular bundles (*fv*); and (4) *endocarp* of stone cells (st^2, st^3, and *iep*).

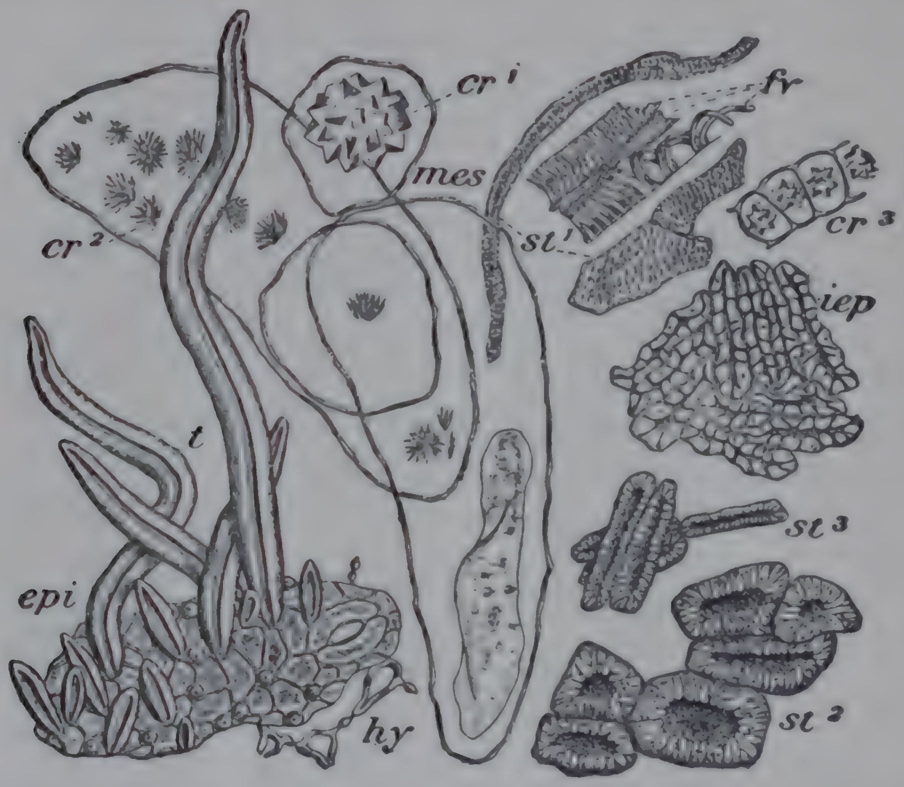

FIG. 227.—Peach. Elements of pericarp in surface view. *epi* epicarp with *t* hairs; *hy* hypoderm; *mes* mesocarp parenchyma with cr^1 oxalate crystal rosette and cr^2 rosettes of needle-shaped crystals; *fv* fibro-vascular bundle with st^1 accompanying sclerenchyma fiber and stone cells and cr^3 crystal fibers; st^2 isodiametric and st^3 elongated stone cells of outer and middle endocarp; *iep* inner cells of endocarp. × 160. (K.B.W.)

The vessels of the *fibro-vascular bundles* are pitted, reticulated, and spiral. Adjoining the bundles are crystal fibers (cr^3), each cell with a small crystal rosette, also pitted sclerenchyma cells and fibers (st^1) differing from those in the apricot in having thin walls.

Spermoderm, Perisperm, Endosperm, and **Embryo.**—See Peach Kernel, Volume I.

CHIEF STRUCTURAL CHARACTERS.—Fruit variously shaped and colored, velvety with hairs; fruit flesh (mesocarp) clinging to or free from stone; endocarp thick, hard, deeply furrowed and pitted. Seed elongated, pointed, smaller than in almond and apricot.

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[1] Z. Naturw. 1886, **59**, 295.

Epicarp hairs thick-walled (thinner-walled in apricot), pointed at base (globular in apricot); mesocarp parenchyma with typical oxalate rosettes, crystal fibers, and rosettes of needle-shaped crystals; endocarp of colorless stone cells of varying forms with dark contents.

CHEMICAL COMPOSITION.—Colby and Dyer[1] secured the following data in the analysis of fruit of the Orange Cling and Lemon Cling varieties respectively: weight of whole fruit 153.5 and 215.5 grams, flesh 93.9 and 93.7 per cent, pits 6.1 and 6.3 per cent; water in whole fruit 78.50 and 86.50 per cent, ash 0.62 and 0.44 per cent; juice in flesh 79.1 and 76.2 per cent; marc in flesh 20.9 and 14.0 per cent; acids as malic in juice 0.23 and 0.44 per cent; sugars in juice 20.00 and 14.00 per cent. The results on sugars appear to be abnormally high.

Kulisch[2] analyzed peaches of 2 varieties, Amsden and Schöne von Doue', obtaining: weight 71.4 and 58.0 grams, pits 3.6 and 3.9 per cent, also the following in percentages of the pulp, solids 11.3 and 10.9, protein 1.11 and 0.81, acids as malic 0.52 and 0.50, reducing sugars 2.05 and 2.14, sucrose 5.52 and 5.72, and ash 0.42 and 0.62 per cent.

Hotter[3] gives analyses of the pulp of 5 samples of Austrian peaches showing the following range: total solids 15.7 to 17.7, insoluble solids 2.6 to 4.2, extract 13.6 to 14.9, total sugars as invert 8.8 to 10.9, dextrose 4.2 to 7.0, levulose 3.9 to 4.9, sucrose 5.0 to 7.1, acids as malic 0.6 to 1.2, tannin 0.06 to 0.22, total ash 0.51 to 0.60, and phosphoric acid 0.05 to 0.08 per cent.

The average of 2 analyses of the pulp by Olig[4] follow: water-soluble matter 9.40 per cent); water-insoluble matter 1.53 per cent; acids as citric 0.77 per cent (as malic 0.74 per cent); invert (reducing) sugar 3.96 per cent; sucrose 2.03 per cent; total ash, 0.51 per cent, alkalinity of ash 52 cc. N/10 acid per 100 grams of pulp; phosphoric acid, total 0.043 per cent, water-soluble 0.040 per cent.

Relation of Structure to Composition.—A comparison of the histological structure, physical characters, and chemical composition, made by Blake, Davidson, Addoms, and Nightingale,[5] showed a correlation of firmness and non-melting characters with thick, unbroken cell walls and high cellulose and protopectin content. High soluble carbohydrate content is more likely to be associated with high color, greater firmness, and better edible characters than is high nitrogen content.

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[1] California Agr. Exp. Sta. 1891/2, p. 92.

[2] Z. angew. Chem. 1894, p. 148.

[3] Z. landw. Versuchsw. 1906, **9**, 747.

[4] Z. Unters. Nahr.-Genussm. 1910, **19**, 558.

[5] New Jersey Agr. Exp. Sta. 1931, Bul. **525**.

Influence of Leaf Area on Composition.—Weinberger and Cullinan,[1] by increasing the number of leaves per fruit from 10 to 80, secured an increase of sugars in the fresh fruit from 7.2 to 12.3 per cent.

Changes in Composition During Growth, Ripening and Storage.—Goessmann [2] determined reducing sugars and sucrose in the juice of 2 varieties at different stages with results respectively as follows: Early York, nearly ripe 1.36 and 4.12, ripe 1.92 and 6.09; Crawford, nearly ripe 2.19 and 7.02, not mellow 1.67 and 5.92, mellow 1.70 and 8.94 per cent. Since the total solids in the pulp of the Crawford variety at the stages recorded as "not mellow" and "mellow" were nearly alike, namely 11.88 and 11.36 per cent, the increase in sucrose was in weight as well as in percentage.

Extensive experiments carried out by Bigelow and Gore [3] as shown below, involved analyses of 6 varieties, namely Triumph, Rivers, Early Crawford, Elberta, Heath Cling, and Smock, from early June to late August, also of 3 varieties, Elberta, Smock, and Stump, when market-ripe and fully ripe, and of 4 varieties, Rivers, Heath Cling, Smock, and Switzerland, at the time of hardening of the stone (endocarp or shell of pit) and after refrigeration for eight days:

Composition of Peach Flesh (Bigelow and Gore)

	Weight	Flesh	Pits	Kernels	Protein	Protein, pure	Acids*	Sugars, reducing	Sucrose	Ash
	g.	%	%	%	%	%	%	%	%	%
June drop aver.†	**9.5**	**64.5**	**35.5**	**2.9**	**0.98**	**0.77**	**0.38**	**2.71**	**0.18**	**0.75**
Stone hard aver.†	**16.8**	**71.5**	**28.7**	**2.9**	**0.81**	**0.63**	**0.46**	**2.26**	**1.57**	**0.68**
Market ripe:†										
Min.	54.6	90.8	6.5	0.5	0.22	0.19	0.44	1.27	4.03	0.46
Max.	98.6	93.5	9.2	0.9	0.44	0.33	1.00	2.23	6.14	0.53
Aver.	**73.6**	**92.5**	**7.5**	**0.6**	**0.35‡**	**0.27‡**	**0.77**	**1.98**	**5.70**	**0.50§**
Market ripe aver.‖	**76.1**	**92.1**	**7.9**	**0.7**	....	....	**0.73**	**2.20**	**6.23**	**0.57**
Full ripe aver.‖	**85.1**	**91.9**	**8.1**	**0.6**	....	....	**0.66**	**2.27**	**7.36**	**0.55**
Stone hard aver.§	**15.8**	**71.6**	**28.4**	**3.1**	**0.81**	....	**0.49**	**2.22**	**1.36**	**0.82**
Refrigerated aver.§	**14.8**	**71.0**	**29.0**	**2.4**	....	....	....	**2.90**	**0.31**	....

* As malic. † 6 varieties. ‡ 5 varieties. § 4 varieties. ‖ 3 varieties.

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[1] Proc. Am. Soc. Hort. Sci. 1931, **28**, 18; 1932, **29**, 23.

[2] Massachusetts Agr. Exp. Sta. Rep. 1889, p. 302.

[3] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **97**.

The influence of different kinds of storage on composition is shown by the average daily changes, in terms of percentages of the original flesh solids, given in the table which follows:

Average Daily Changes in Peach Solids During Storage (Bigelow and Gore)

Storage	Time of storage	Solids	Marc	Acids as malic	Sugars, reducing	Sucrose	Undetermined
	days	%	%	%	%	%	%
Common (25°–30° C.) . .	2–10	−3.117	−1.751	−0.055	+1.601	−1.778	−1.120
Cold (0° C.)	28–63	−0.221	−0.017	−0.075	+0.024	−0.257	+0.085
Refrigerator (12°–15° C.	8–10	−0.722	−0.319	−0.116	−0.419	−0.699	+0.798

In experiments designed primarily to study the influence of various fertilizers, Tarr[1] found that only starch and reducing sugars were present during the early stages of growth. During the ripening period starch disappeared, sucrose appeared and progressively increased, and reducing sugars stabilized at 2.25 to 2.75 per cent.

Pickett[2] has carried out experiments on the storage of peaches frozen at −15° and 65° C. in hypoisotonic and hyperisotonic solutions of sucrose and common salt. The quickly (−65°) frozen fruit was lower in soluble pectin and higher in protopectin than the slowly (−15°) frozen.

Respiration.—Gore,[3] working with 5 varieties of peaches, noted a maximum evolution of 134 mg. of carbon dioxide per kilo per hour at 31.4° C. in one case and 29.2° C. in another and a minimum of 6 mg. at 1.1° C.

Influence of Irrigation.—Sucrose, according to Leoncini and Rogai,[4] persists in peaches and plums into the last period of ripening, but this is less pronounced when the trees are heavily irrigated.

Influence of Fertilizers.—Analyses were made on several dates, by Nightingale, Addoms, and Blake,[5] of peaches from trees fertilized with large and small amounts of nitrogen. Results showing changes from the unripe (July 22) to fully ripe (Aug. 31 to Sept. 9) fruit of high and of low nitrogen trees were respectively as follows: solids 12.40 to 12.68,

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[1] Delaware Agr. Exp. Sta. 1921, Bul. **129**.

[2] Georgia Agr. Exp. Sta. Rep. 1931, p. 42.

[3] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[4] Boll. ist. super. agr. Pisa 1932, **8**, 777.

[5] New Jersey Agr. Exp. Sta. 1930, Bul. **494**.

13.86 to 13.60; protein 1.64 to 0.71, 0.64 to 0.28; pure protein 0.48 to 0.20, 0.38 to 0.19; soluble protein 1.11 to 0.52, 0.39 to 0.08; acidity (cc. *N*/50 alkali per 10 cc. juice) 37 to 45, 37 to 48; reducing sugars 2.80 to 1.53, 3.10 to 2.63; sucrose 0.17 to 5.69, 0.20 to 6.44; soluble pectin 0.36 to 0.34, 0.38 to 0.44; protopectin 0.47 to 0.07, 0.82 to 0.13; hemicellulose 0.62 to 0.17, 0.55 to 0.17; tannin 0.005 to 0.004, 0.082 to 0.003; and ash 1.39 to 0.69, 1.26 to 0.51 per cent.

Relation of Pectin Content to Ripeness.—During ripening, according to Appleman and Conrad,[1] protopectin changes into pectin, the sum of the two remaining practically constant until full ripeness when both begin to decrease. The progress of softening of the fruit parallels the formation of pectin from protopectin. Softening is accelerated by heat and retarded by cold, and proceeds more rapidly after picking, even if the temperature remains the same. Cold storage for a considerable time impairs the flavor of the fruit.

Relation of Composition to Canning Qualities.—Peaches for canning, according to Culpepper and Caldwell,[2] should be picked when the flavor is well developed but before there is danger of disintegration in processing. The "pressure test," that is the resistance offered by the unpared flesh to perforation by a blunt needle 0.8 mm. in diameter, is a reliable measure of maturity. Selected results appear in the table below:

COMPOSITION OF FLESH OF CANNING PEACHES AT DIFFERENT STAGES OF RIPENESS (CULPEPPER AND CALDWELL)

	Before or after ripe	Solids	Alcohol extract	Acids as citric	Sugars, reducing	Sucrose	Tannin	Non-tannin	Pressure test
	days	%	%	%	%	%	%	%	g.
J. H. Hale:									
Unripe	5–6	13.24	10.56	0.59	3.54	4.55	0.10	0.11	316
Ripe	0	13.06	10.96	0.57	3.36	5.58	0.07	0.10	309
Overripe	6–7	13.52	11.48	0.45	3.66	6.05	0.03	0.11	162
Elberta:									
Unripe	6–7	14.17	11.28	0.72	3.51	5.50	0.06	0.16	323
Ripe	0	14.98	12.60	0.73	3.68	6.69	0.05	0.14	295
Overripe	6–7	13.45	11.64	0.48	2.46	7.55	0.02	0.13	134
Yellow Hiley:									
Unripe	6–7	13.59	10.40	0.73	3.48	3.50	0.04	0.12	358
Ripe	0	13.32	10.84	0.66	2.72	5.61	0.03	0.10	269
Overripe	5–6	12.69	10.73	0.43	2.93	6.10	0.04	0.12	68

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[1] Maryland Agr. Exp. Sta. 1926, Bul. **283**.

[2] U. S. Dept. Agr. 1930, Tech. Bul. **196**.

Composition of Peach Juice.—Results by Truchon and Martin-Claude [1] and Windisch and Schmidt,[2] in some cases recalculated for uniformity, appear in the following table:

COMPOSITION OF PEACH JUICE

(Grams per 100 cc. juice)

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
T. and M.	1	1.054	14.34	....	0.61	3.35	1.98	.....	0.47	..
W. and S.	2									
Min....		1.038	9.70	0.40	0.94	3.06	2.87	0.12†	0.41	43
Max...		1.045	11.60	0.42	1.01	3.80	4.02	0.12†	0.51	53
Aver...		**1.042**	**10.65**	**0.41**	**0.98**	**3.43**	**3.45**	**0.12†**	**0.46**	**48**

* Cc. *N*/10 acid per 100 cc. juice. † 1 sample.

Composition of Kernel.—See Peach Kernel, Volume I.

Acids.—Kunz and Adam [3] concluded that the acid of the peach is *citric* with no malic; Bigelow and Dunbar,[4] that it is probably *malic*; and Nelson,[5] who used the ester-distillation method, that it is a mixture of the *l*-malic and citric in about equal proportion. Muttelet [6] reports malic acid 0.19 and citric acid 0.31 per cent.

Carbohydrates.—Leoncini and Rogai[7] observed that wet weather and a moist condition of the soil reduce the content of sugars.

Odorous Constituents.—The chief odorous constituents of peaches, according to Power and Chesnut,[8] are esters of the aliphatic terpene alcohol *linalool*, $C_{10}H_{18}O$, an isomer of geraniol, with *formic*, *acetic*, *valeric*, and *caprylic acids*, also considerable *acetaldehyde* and small amounts of an aldehyde of higher molecular weight. Neither hydrocyanic acid nor benzaldehyde was detected, and it was concluded that the glucoside amygdalin is present only in the kernels of the pits. An unstable *volatile oil*, present to the extent of 0.00074 per cent in the pulp, was isolated by extracting a concentrated distillate with ether.

[1] Ann. chim. anal. 1901, **6**, 85.

[2] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[3] Ibid. 1906, **12**, 670.

[4] J. Ind. Eng. Chem. 1917, **9**, 762.

[5] J. Am. Chem. Soc. 1924, **46**, 2337.

[6] Ann. fals. 1922, **15**, 453.

[7] Bol. ist. super. agr. Pisa 1933, **9**, 501.

[8] J. Am. Chem. Soc. 1921, **43**, 1725; 1922, **44**, 2966.

On cooling it solidified to a transparent mass containing acicular crystals of a hydrocarbon melting at 52° C. *Acetaldehyde* and *cadinene*, or a compound giving a similar color reaction, were believed to be present in small amounts.

Mineral Constituents.—Kulisch[1] in the flesh of 2 varieties and Haskins[2] in the whole fruit analyzed at the Massachusetts Station report the results given in the following table:

	Water	Ash	K_2O	CaO	MgO	P_2O_5
	%	%	%	%	%	%
Kulisch						
Amsden	88.70	0.415	0.208	0.036	0.020	0.053
Schöne von Doue'	89.10	0.617	0.320	0.012	0.017	0.046
Haskins	88.4	0.34	0.25	0.01	0.02	0.05

Minor Mineral Constituents. *Iron.*—Fruit 3.6 mg. per kilo, fresh basis; dried stoned fruit 60.6 mg. per kilo, as sold (Peterson and Elvehjem).[3] Fruit, 2 samples 5.2, 5.6 mg. per kilo, fresh basis (Toscani and Reznikoff).[4]

Aluminum.—Fruit 8.8 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[5] Fruit 64 mg. per kilo, dry basis (Bertrand and Lévy).[6]

Copper.—Dried stoned fruit 2.7 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[7]

Zinc.—Stoned fruit 0.2 mg. per kilo, fresh basis (Bertrand and Benzon.)[8]

NECTARINE

Prunus Persica var. *nucipersica* Schneid. = *Persica nucipersica* Borkh.

Fr. Pêche lisse. Sp. Abridor. It. Pesca. Ger. Glatte Pfirsich.

Botanists now regard the nectarine as a smooth-skinned variety of the peach. This is in harmony with the similarity of the two fruits in the texture and flavor of the fruit flesh, the furrowed surface of the stone, and the structure of the seed. In external appearance, however, as well as in certain details of structure of the spermoderm, the fruit is more like a plum than a peach, which suggests that possibly it is a hybrid.

[1] Loc. cit.

[2] Massachusetts Agr. Exp. Sta. 1919, Spec. Bul.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Nutrition 1934, **7**, 79.

[5] Am. J. Physiol. 1929, **90**, 72.

[6] Bul. soc. hyg. aliment. 1931, **19**, 359.

[7] J. Biol. Chem. 1929, **82**, 465.

[8] Bul. soc. hyg. aliment. 1928, **16**, 457.

MACROSCOPIC STRUCTURE.—The smooth surface and the furrowed *stone* are the distinctive characters. Clingstone and freestone varieties are cultivated.

MICROSCOPIC STRUCTURE. Pericarp.—The *epicarp* cells (Fig. 228) are distinctly beaded and larger than in the peach, especially about the stomata. Although hairs are generally regarded as entirely absent, a few of the peach type may occur in the groove. Of more frequent occurrence in the mature fruit are hair scars (*x*).

Spermoderm, Perisperm, Endosperm, and **Embryo.**—See Nectarine Kernel, Volume I.

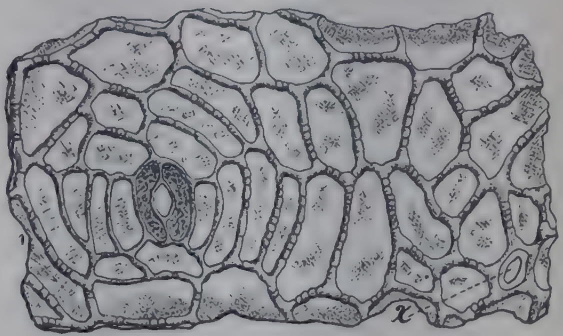

FIG. 228.—Nectarine. Epicarp in surface view. *x* hair scar. × 160. (A.L.W.)

CHIEF STRUCTURAL CHARACTERS.—Hairs and hair scars sparingly present in groove. Fruit otherwise smooth, resembling peach.

CHEMICAL COMPOSITION.—An analysis of California nectarines by Colby[1] yielded as follows: average weight 102.5 grams, pulp 93.4 per cent, pits 6.6 per cent, kernels 0.94 per cent, water 79.00 per cent, protein 0.73 per cent, and ash 0.50 per cent. The pulp (fruit flesh) consisted of juice 89.3 and marc 10.7 per cent; the juice contained acids calculated as malic 0.85 and sugars 17.17 per cent.

SWEET CHERRY

Prunus avium L. = *P. Cerasus* L. var. *avium* L. =
Cerasus avium Moench.

Fr. Putiet. Sp. Cereza. It. Ciliegia. Ger. Süsskirsche.

Mazzards or sweet cherries are derived from a species native in western Asia and also perhaps in Europe. Cultivated varieties are grouped as "Hearts" (var. *Juliana* Bailey) with soft, sweet fruit flesh, "Bigarreaus" (var. *duracina* Bailey) with hard, sweet fruit flesh, and "Dukes" (var. *regalis* Bailey) with soft, acid flesh. Some authors give the three types specific names.

As a dessert and culinary fruit, the cherry is much esteemed, being especially suited for pies and puddings. It is canned, dried, and candied on a considerable scale. Kirschwasser is a liquor of high alcoholic content prepared in Switzerland and neighboring regions. Sweet cherries, artificially colored and flavored, and preserved in syrup, in the United States are popular additions to desserts, salads, punches, etc. Colored red and flavored with benzaldehyde they are known as maraschino cherries, although no true maraschino—the liqueur made in Dalmatia from the sour cherry—is used in their preparation. They are also colored green and flavored with mint. For their preparation, white cherries are imported from Europe in a liquid containing sulphites or sulphurous acid as a preservative which is removed by soaking and washing.

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[1] California Agr. Exp. Sta. Rep. 1892/4, p. 257.

MACROSCOPIC STRUCTURE.—The *flowers* are produced in clusters on long peduncles. White petals and smooth calyx tube and reflexed calyx lobes characterize both sweet and sour varieties, the tube of the former being distinctly constricted at the top, while that of the latter is practically without constriction. The *fruit* is small with a nearly globular small *stone*, but in general structure is like the plum. There are white, red, and black varieties.

MICROSCOPIC STRUCTURE. Pericarp.—The chief distinction from the plum lies in the larger size of the cells of the *epicarp* which, measured in surface mounts, reach over 100 μ in diameter. Indistinct beads are present in the walls which are somewhat thickened. Division into daughter cells is not marked. About the stomata the cells are smaller and thinner-walled.

Hypoderm.—In cross section the cells are seen to be flattened; in surface view they are rounded with intercellular spaces at the angles.

Mesocarp.—Among the large pulp cells are smaller ones, each with a crystal rosette. Smaller cells also adjoin the endocarp. The fibrovascular bundles contain spiral, reticulated, and pitted vessels. Small sclerenchyma fibers accompany the bundles.

In the *outer endocarp*, forming the bulk of the woody tissue, the stone cells are isodiametric; in the inner part, consisting of but a few rows, they are narrow and transversely elongated. A layer several cells thick of longitudinally elongated forms, such as occur in the larger drupes, is absent. The cells are thick-walled and finely pitted with colorless walls and contents.

Spermoderm, Perisperm, Endosperm, and **Embryo.**—See Cherry Kernel, Volume I.

CHIEF STRUCTURAL CHARACTERS.—Fruit small, sweet, black, red, or yellow; stone small, usually globular.

Epicarp cells large (100 μ); mesocarp without stone cells; outer endocarp of isodiametric stone cells, inner endocarp of transversely elongated stone cells.

CHEMICAL COMPOSITION.—Analyses of 2 European varieties by Kulisch,[1] of 3 California varieties, Royal Ann, Black Tartaric, and Napoleon Bigarreau, by Colby,[2] and of 13 Oregon varieties by Shaw[3] are summarized below:

COMPOSITION OF CHERRIES

	Weight	Flesh	Pits	Juice	Marc	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Ash
	g.	%	%	%	%	%	%	%	%	%	%
Kulisch:											
Brown-red.	3.8	....	9.5	....	....	14.50*	1.26*	0.51*	11.99*	0.46*	0.38*
Mountain .	4.5	....	6.9	....	....	21.40*	1.14*	0.99*	15.38*	....	0.41*
Colby:											
Min.	6.2	94.0	3.3	79.1	11.3	18.12	1.14	0.37	8.98†		....
Max.	8.5	96.7	6.0	89.7	20.9	24.82	1.73	0.68	12.75†		....
Aver.	**7.6**	**95.4**	**4.6**	**83.4**	**16.7**	**20.57**	**1.41**	**0.48**	**10.96†**		....
Shaw:											
Min.	2.9	90.9	3.6	80.0*	8.3*	14.00*	0.70*	0.16§	7.30‡		0.46*
Max.	7.8	96.4	10.1	91.7*	20.0*	25.28*	1.20*	0.82§	12.85‡		1.00*
Aver.	**5.3**	**93.9**	**5.3**	**86.4***	**13.1***	**18.75***	**0.91***	**0.43§**	**10.40‡**		**0.53***

* Per cent in flesh. † Total sugars calculated to the juice 11.41 to 15.77, aver. **13.86**%.
‡ Total sugars calculated to the juice 8.64 to 16.46, aver. **12.29**%. § Per cent in juice.

Analyses of the flesh of 6 samples of Austrian cherries reported by Hotter[4] show the following range: total solids 14.7 to 22.3, insoluble solids 2.1 to 2.5, extract 13.1 to 19.9, total sugars as invert 8.8 to 13.9, dextrose 5.3 to 7.8, levulose 3.4 to 5.8, sucrose 0.4 to 0.8, acids as malic 0.4 to 0.8, tannin 0.05 to 0.15, total ash 0.43 to 0.60, and phosphoric acid 0.04 to 0.07 per cent.

Analyses on a somewhat different plan of 3 samples of cherry flesh by Olig[5] yielded as follows:

COMPOSITION OF CHERRY FLESH (OLIG)

	Solids, sol.	Solids, insol.	Acids as malic	Invert sugar	Ash, total	Ash, alk.*	P_2O_5 total	P_2O_5 water-sol.
	%	%	%	%	%		%	%
Min. . .	10.50	1.41	0.46	7.86	0.47	42	0.043	0.038
Max. .	14.52	2.09	0.94	11.34	0.68	73	0.065	0.056
Aver. .	**12.43**	**1.73**	**0.73**	**9.60**	**0.59**	**58**	**0.053**	**0.046**

* Cc. *N*/10 acid per 100 grams fruit.

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[1] Z. angew. Chem. 1894, p. 148.

[2] California Agr. Exp. Sta. Rep. 1894/5,, p. 177.

[3] Oregon Agr. Exp. Sta. 1898. Bul. 55.

[4] Z. landw. Versuchsw. 1906, 9, 747.

[5] Z. Unters. Nahr.-Genussm. 1910, 19, 558.

Composition of Cherry Juice.—Truchon and Martin-Claude[1] and Windisch and Schmidt[2] obtained the results here tabulated:

COMPOSITION OF CHERRY JUICE

(Grams per 100 cc. juice)

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as malic	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
T. and M.-C.:										
Early.....	1	1.040	0.34†	....	0.44	8.36	0.00	....	0.30	..
Late......	1	1.055	0.24†	....	0.75	9.68	0.00	....	0.39	..
W. and S.:										
Sour	9									
Min....		1.045	11.70	0.33	0.99	6.98	0.26	0.13‡	0.38	38
Max....		1.081	21.15	0.75	1.87	12.89	1.07	0.15‡	0.57	57
Aver....		**1.064**	**16.80**	**0.43**	**1.40**	**9.32**	**0.96**	**0.14‡**	**0.48**	**49**
Sweet.....	20									
Min.....		1.044	11.25	0.32	0.46	7.07	0.00	....	0.38	39
Max....		1.092	23.96	0.83	0.83	14.58	0.67	....	0.62	60
Aver....		**1.067**	**17.56**	**0.48**	**0.64**	**11.10**	**0.26**	**0.09§**	**0.48**	**49**

* Cc. *N*/10 acid per 100 cc. juice. † Alcohol precipitate. ‡ 3 samples. § 1 sample.

Hotter,[3] in the analysis of several varieties ranging in color from black to yellow, obtained results falling in general within the range given in the above table.

Composition of Kernel.—See Cherry Kernel, Volume I.

Changes in Composition during Ripening.—Analyses by Keim[4] made up to full ripeness (June 19) show progressive increase in solids,

COMPOSITION OF CHERRIES DURING GROWTH AND RIPENING (KEIM)

	Weight	Solids	Acids as malic	Sugars, reducing	Sucrose	Ash
	g.	%	%	%	%	%
May 15....	6.4	11.12	0.21	2.74	0.19	0.48
May 21....	8.3	16.27	0.31	3.13	....	0.52
May 28....	13.2	17.87	0.41	4.14	0.28	0.65
June 10....	30.8	16.37	0.42	9.12	1.17	0.66
June 19....	37.2	18.78	0.46	10.26	....	0.74

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[1] Ann. chim. anal. 1901, **6**, 85.

[2] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[3] Graz pomolog. Vers.-Stat. Ber. 1894 et seq.

[4] Z. anal. Chem. 1891, **30**, 401.

acids, sugars, and ash as here given. Inosite was found in both the green and ripe fruit.

Hartman and Bullis[1] show that sugars and non-sugar solids increase greatly whereas acidity, tannin, astringency, and color decrease during ripening. The firmness is determined by a special pressure tester.

COMPOSITION OF UNRIPE AND RIPE CHERRIES (HARTMAN AND BULLIS)

Date	Acids as malic	pH	Sugars	Non-sugar solids
	%		%	%
1926				
June 4	0.90	3.29	10.6	3.9
July 26	0.71	3.81	18.8	7.1
1927				
June 23	0.75*	3.68	7.4	3.4
Aug. 1	0.72*	3.96	16.5	6.2

* The lowest acidity was 0.62% on July 20, the highest was 0.82% on June 26.

Acids.—Bigelow and Dunbar,[2] after studying results obtained by Dunbar, by Clark, by Johnson, and by Fitzgerald and Dunbar, all of the same laboratory, showing 0.56 to 2.01 per cent of acid as malic by titration and practically the same amounts by determination of malic acid, conclude that *malic* is the sole acid present. In this conclusion they wholly agree with Kunz and Adam[3] and substantially with Jörgensen,[4] who found in addition only traces of *succinic* and *citric acids*, and Muttelet,[5] who found malic acid and mere traces of *tartaric acid* and later[6] 0.82 to 1.61 per cent of malic acid in different varieties. They disagree with Keim,[7] who found both malic and citric, Truchon and Martin-Claude,[8] who found tartaric and traces of citric in unripe cherries but no citric in the ripe, Roux and Bonis,[9] who, while admitting that malic acid predominates, assert that citric and tartaric acids also are present, and Traetta-Mosca, Papocchia, and Galimberti,[10] who report malic, citric, and tartaric acids.

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[1] Oregon Agr. Exp. Sta. 1929, Bul. **247**.

[2] J. Ind. Eng. Chem. 1917, **9**, 762.

[3] Z. Unters. Nahr.-Genussm. 1906, **12**, 670.

[4] Ibid. 1907, **13**, 241.

[5] Ann. fals. 1909, **2**, 383.

[6] Ibid. 1922, **15**, 453.

[7] Z. anal. Chem. 1891, **30**, 401:

[8] Ann. chim. anal. 1901, **6**, 85.

[9] Ann. fals. 1909, **2**, 150.

[10] Ann. chim. appl. 1923, **13**, 333.

Enzymes.—Traetta-Mosca, Papocchia, and Galimberti[1] found no oxidase in black cherries and *peroxidase* only in the unripe fruit. *Invertin* and *amylase* were present in the pulp and *emulsin* in the seed in all stages of growth.

Mineral Constituents.—An ash analysis of European cherries by Keim,[2] after calculating free of 19.5 per cent of carbon dioxide, agrees in most respects quite closely with one by Colby:[3]

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
Keim..	54.98	1.66	6.46	5.77	2.05	1.01	....	19.85	3.96	2.29	1.53
Colby..	57.67	6.80	4.20	5.49	1.12	....	0.82	15.11	5.83	1.13	1.83

Minor Mineral Constituents. *Iron.*—Red 3, black 4 mg. per kilo, fresh basis (Bunge quoted by Sherman).[4] Fruit: black 14 mg. per kilo, fresh basis (Häusermann quoted by Sherman).[4] Fruit: red 4.6, black 5.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[5]

Aluminum.—Stoned fruit 34.9 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[6] Fruit 70 mg. per kilo, dry basis (Bertrand and Lévy).[7]

Copper.—Fruit fresh basis 1.6, dry basis 15.6 mg. per kilo (Guérithault).[8] Stone: kernel 27, shell 12 mg. per kilo, dry basis (Maquenne and Demoussy).[9] Stoned fruit 1.4 mg. per kilo, fresh basis (Lindow, Elvehjem, Peterson).[10]

Zinc.—Sour cherry, edible part 1.5 mg. per kilo, fresh basis (Bertrand and Benzon).[11]

Iodine.—None (Winterstein).[12]

SOUR CHERRY

Prunus Cerasus L. = *Cerasus vulgaris* Mill.

Fr. Griotte. Ger. Sauerkirsche.

This species is more hardy than the sweet cherry. It probably originated in western Asia and is grown in Europe and America. Two groups are recognized, the morellos with dark fruit and the amarelles with light fruit.

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[1] Loc. cit.

[2] Loc. cit.

[3] Loc. cit.

[4] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] Am. J. Physiol. 1929, **90**, 72.

[7] Compt. rend. 1931, **192**, 525.

[8] Ibid. 1920, **171**, 196.

[9] Ibid. 1920, **170**, 87.

[10] J. Biol. Chem. 1929, **82**, 465.

[11] Bul. soc. hyg. aliment. 1928, **16**, 457.

[12] Z. physiol. Chem. 1918, **104**, 54.

They are too sour for eating out of hand but are excellent for cooking. The liqueur maraschino is made in Dalmatia from this species.

MACROSCOPIC STRUCTURE.—See Sweet Cherry.

MICROSCOPIC STRUCTURE. Pericarp.—No difference in structure of the sweet and sour cherry has been noted.

CHEMICAL COMPOSITION.—See Sweet Cherry.

ICACO

Chrysobalanus Icaco L.

Fr. Prune icaque. Sp. Icaco. Ger. Ikakopflaume.

Hicaco is another spelling and cocoa plum another name for the fruit. According to Sargent[1] it is a native of Florida, West Indies, Brazil, and the West Coast of Africa.

Though not a valuable dessert fruit, it is much used for making preserves. Chace, Tolman, and Munson,[2] in their studies of the chemical composition of Cuban fruits, found the icaco on sale in Cuba both fresh and packed in glass and tin.

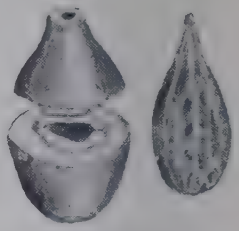

FIG. 229.—Icaco. Left, fruit; right, stone. × ½. (A.L.W.)

MACROSCOPIC STRUCTURE.—Excepting the style which is attached to the base of the ovary, the raphe which is dorsal, and the ascending ovules, the *flower* is similar to flowers of the species of *Prunus*. There are five calyx lobes, five petals, and about twenty stamens, petals and stamens being attached to the disk in the calyx throat. Of the two ovules only one becomes a seed.

Externally the *fruit* (Fig. 229) is plum-like—but is narrowed at the base—and has about the same range of colors. The fruit flesh has a tendency to be cottony, which is explained below. The *stone* is five- to eight-angled, reticulated between the angles, and pointed at the base. It splits at the angles. Cross sections show that the endocarp is about 1 mm. thick, the spermoderm is thin, and the cotyledons are fleshy filling the locule except for a more or less pronounced central cavity.

MICROSCOPIC STRUCTURE.—Microscopically the fruit and seed have little in common with those of the prunus drupes.

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[1] Manual Trees of North America, Boston, 1905, p. 532.

[2] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87, 28.

Pericarp.—Four layers are present: (1) *epicarp* of thin-walled polygonal calls, up to 25 μ in diameter, and occasional rather large stomata but no hairs; (2) *hypoderm* of small slightly thickened isodiametric cells; (3) *mesocarp* of thin-walled pulp cells, mostly elongated and arranged end to end in radial rows, also fibro-vascular bundles with accompanying bast fibers and sclerenchyma fibers; and (4) *endocarp* of fiber-like elongated, thick-walled, sclerenchyma cells running in groups in different tangential directions.

The radially elongated cells of the *mesocarp* explain the so-called cottony nature of the fruit flesh. *Fibro-vascular bundles* are numerous adjacent to the endocarp. *Crystal rosettes* occur in small cells throughout the mesocarp, also in crystal fibers near the bundles.

Spermoderm.—Differentiation into well-defined layers and epidermal sclerenchyma cells, characteristic of the species of *Prunus*, is not evident in the icaco. The more or less brown cells are inconspicuous and neither *outer* nor *inner epiderm* is well marked. Bundles of the raphe and its branches are conspicuous.

Perisperm.—Not evident.

Endosperm.—The endosperm is reduced to a single or in places double layer of typical *aleurone cells.*

Embryo.—The cotyledons are rich in fat and aleurone grains, but the structure of the latter is obscured by other cell contents which do not dissolve in turpentine mounts.

CHIEF STRUCTURAL CHARACTERS.—Fruit plum-like, smooth; mesocarp cottony; stone five- to eight-angled; endocarp hard, 1 mm. thick. Spermoderm thin, brown; endosperm thin, colorless; cotyledons bulky, about central cavity.

Mesocarp cells radially elongated; endocarp entirely of sclerenchyma fibers. Spermoderm characterless, without sclerenchyma cells. Contents of cotyledons aleurone grains and fat.

CHEMICAL COMPOSITION.—Analyses by Chace, Tolman, and Munson [1] of the flesh of 2 samples grown in Cuba follow:

	Weight	Flesh in fruit	Solids, total	Solids, insol.	Protein	Acids as malic	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	cc.
I.....	8	69	14.29	4.74	0.46	....	5.18	0.00	0.96	105
II....	8	70	13.59	....	....	0.13	4.18	0.36	0.91	79

* Cc. $N/10$ acid per 100 grams pulp.

[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87.

Mineral Constituents.—Chace, Tolman, and Munson[1] found 0.91 per cent of ash in the pulp and the following percentages of constituents in the ash:

K_2O	CaO	MgO	P_2O_5	SO_3	Cl
%	%	%	%	%	%
35.15	5.84	4.51	3.09	4.77	18.62

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[1] Loc. cit.

FRUITS OF THE PEA FAMILY

(*Leguminosæ*)

WHILE most food legumes are distinctly vegetables or fodder plants, the tamarind, carob, and kamanchile are here classified with fruits. The tamarind pod is characterized by its intense acidity which gives it much the same value as the lemon; the carob pod, on the other hand, is markedly sweet and in addition contains tannin bodies ("Inklusen") of remarkable form and properties. Only the aril of the kamanchile is eaten.

TAMARIND

Tamarindus indica L.

Fr. Tamarin. Sp. Tamarindo. It. Tamarindo. Ger. Tamarinde.

A native of tropical Africa, Australia, and probably Asia, the tamarind tree is grown throughout the tropics for its acid fruit, the pulp of which, made into cakes, paste, or packed in casks with sugar, is used in foods, drugs, and cooling drinks.

MACROSCOPIC STRUCTURE.—Luerssen[1] shows an excellent cut of the *flower* in longitudinal section. Of the four pointed calyx lobes the upper belongs to two united sepals. Three of the five petals are yellow and showy, while the two lower petals are reduced to bristles. The stalk of the elongated pistil is grown to the calyx tube. Of the nine stamens, only three develop and the filaments of these are united for about half their length.

The *pod* (Fig. 230) of the East Indian tamarind often reaches 20 cm. in length and contains a dozen or more seeds, but that of the West Indian variety (*T. occidentalis* Gaertn.) is commonly shorter and fewer-seeded. The peduncle is jointed, 2 to 3 cm. long. The pod is rounded triangular with a main longitudinal bundle in each angle and two or three others embedded between the two ventral angles, all running the entire length of the pod and with numerous fine lateral branches. The harsh, brittle, brown rind, about 1 mm. thick, may be removed readily from the septate pod, exposing the soft mesocarp, from which in turn may be separated the bundles and the seeds, each of the latter being completely enclosed in a parchment-like endocarp.

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[1] Handb. Syst. Botan. Leipzig, 1882, 2, 899.

The *seeds* are flattened, more or less rounded quadrilateral, brown, strongly lustrous at the edges but with a somewhat dull, slightly depressed and distinctly outlined patch on the center of each side. The seed, unlike its near relatives the carob bean and coffee cassia, is orthotropous, the hilum and micropyle being on opposite edges. The hilum is recognized by the remnants of a torn-off funiculus and the micropyle by its uniform circular raised border. A faint ridge on the edge of the seed might be mistaken for a raphe but it runs completely around and not to a chalaza. The hilum is directly over the short, straight (not recurved) radicle which is about one-quarter of the length of the fleshy cotyledons, these latter being notched to receive it. Neither endosperm nor perisperm is evident.

MICROSCOPIC STRUCTURE.—Meager descriptions are given in works on pharmacognosy.

Peduncle.—Cross sections show: (1) *cork cells* with brown contents, (2) brown *parenchyma* and *stone cells*, (3) *pericycle* of stone cells and crystal cells, (4) *phloem zone* with crystal fibers, (5) *cambium*, (6) *xylem zone* of vessels and bast fibers, and (7) *pith*.

Pericarp (Fig. 231).—Six layers are present, of which the first two form the rind: (1) *epicarp* of cork cells, several thick, often with thickened inner and side walls; (2) *hypoderm* of a dense mass of stone cells with dark contents, increasing in size from without inward, and narrow radial rows of parenchyma; (3) *mesocarp* of parenchyma containing starch (*am*) up to 12 μ and beautiful crystals of potassium (or calcium) bitartrate (*cr*), also fibro-vascular bundles; (4) *fibers* (*sc*), about 15 μ broad with distinctly beaded walls; (5) *brown parenchyma* (*p*) with cells smaller than in the mesocarp; and (6) *endocarp* (*end*) of colorless fibers less than 10 μ broad with scarcely visible lumens.

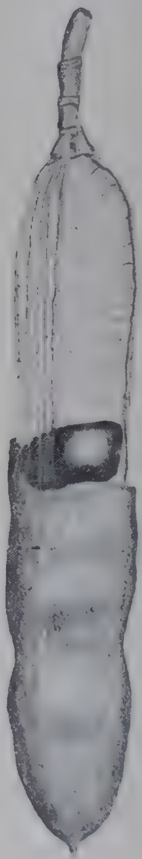

FIG. 230.—Tamarind. Pod with peduncle. × ½. (A.L.W.)

Spermoderm (Fig. 232, *S*).—On the center of the dull patches five layers are differentiated: (1) *palisade cells* (*pal*), 135 μ high and 10 μ broad, forming the epiderm, with a cuticle (*c*); (2) *subepiderm* (*sub*) of spool- or bone-shaped cells up to 50 μ high and 25 μ broad, one to three thick, containing disorganized chlorophyl grains (*ch*) or deep brown contents, passing into (3) *thick-walled parenchyma* (p^1), varying from isodiametric in the outer to transversely elongated cells in the inner layers; (4) *radially elongated parenchyma* (p^2); and (5) *inner epiderm* (*iep*) of small cells with thick walls.

The remarkable *palisade cells* resemble in some respects those of cotton seed. In addition to a bulb at the inner end of each cell, there is another (y) a little below the center, both containing a brown substance. About one-third the distance from the inner bulb to the cuticle is a short region (w) with wart-like spots. The color of the walls between the cuticle and the middle bulb is yellow, about the middle bulb it is a deeper yellow, while between the two bulbs it is colorless. Polarized light brings out a play of colors except in the warty portion and the extreme inner end.

Proceeding from the dull patches toward the lustrous margin of the seed, the middle bulb and warty region move nearer and nearer the outer ends of the cell until they are lost in the cuticle. Their disappearance is accompanied by an increase in height of the cells to about 160 to 175 μ. In the region of the hilum, there is a further increase to about 250 μ and then an abrupt disappearance of the cells at the hilum while about the micropyle there is a gradual shortening and disappearance.

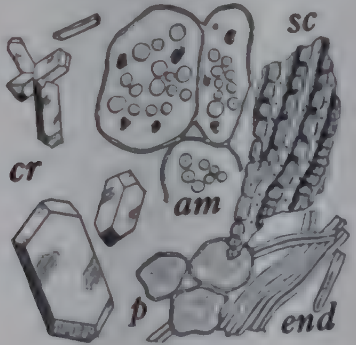

FIG. 231.

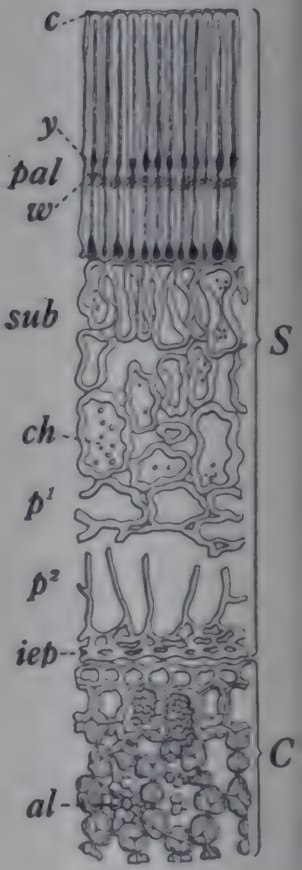

FIG. 232.

FIG. 231.—Tamarind. Pericarp tissues in commercial paste. *am* starch parenchyma; *cr* potassium bitartrate crystals; *sc* sclerenchyma; *p* parenchyma; *end* endocarp. × 160. (A.L.W.)

FIG. 232.—Tamarind. Seed in cross section. *S* spermoderm: *pal* palisade epiderm with *c* cuticle, *y* yellow band, *w* warty band; *sub* subepiderm with *ch* chlorophyl grains; p^1 outer, p^2 inner parenchyma; *iep* inner epiderm. *C* cotyledon of thick-walled beaded cells, *al* aleurone grains. × 160. (A.L.W.)

The *subepidermal cells* vary considerably in the different parts. On the edges of the seed all the inner layers are strongly developed.

Perisperm and **Endosperm** appear to be entirely lacking at full maturity.

Embryo (Fig. 232, *C*).—Reserve carbohydrate in the cell wall, such as is present in the endosperm of the carob bean and coffee cassia, is here found in the cotyledons, but in the form of amyloid, not mucilage.

As first noted by Nägeli,[1] the thickened porous walls stain blue with odine in potassium iodide. The cell cavities contain fat and protein in granules of obscure structure.

Chief Structural Characters.—Pulp containing long stringy bundles. Quadrilateral brown seeds, with lustrous margins and dull patches on the sides, encased in sacs of endocarp.

Pulp containing bitartrate crystals, starch cells, cork cells, stone cells of various sizes, broad fibers with beaded walls, and narrow fibers with scarcely any lumen. Palisade cells with two bulbs, thick-walled subepiderm of spermoderm, and cotyledons with thick, beaded walls, staining blue with iodine, highly characteristic.

CHEMICAL COMPOSITION.—A study of results by Chace, Tolman, and Munson,[2] Pratt and Del Rosario,[3] and Thompson [4] shows that the fruit flesh is highly acid, indeed it is stated to be the most strongly acid of all natural food products. When immature the seeds are soft and edible but the flesh is deficient in acidity at this stage.

Composition of Tamarind Flesh

	Flesh in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as tartaric	Sugars reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
C. T. and M.:											
I.	. .	52.53	8.61	1.36	. . . .	9.23	31.00	0.43	. . . .	1.56	199
II.	51	64.75	. . . .	2.44	. . . .	14.24	29.31	1.05	. . . .	. . . .	. . .
P. and Del R.:											
Green.	100	85.0	10.1	1.41	. . . .	3.98	0.00	0.00	. . . .	4.21	559
Ripe.	50	82.2	8.8	3.00	. . . .	15.33	40.20	0.94	. . . .	3.16	401
Thompson. . . .	48	69.51	17.68	3.43	0.85	17.33	18.74	2.58	5.61	1.82	. . .

* Cc. *N*/10 acid per 100 grams fruit.

Hooper[5] gives the following percentages of parts: pulp 55, seed 33.9, shell and fiber 11.1. His analyses of the whole and decorticated seed are given on the next page.

Oil. *Physical and Chemical Values.*—The oil obtained by ether extraction of the seed, according to Hooper,[5] is semi-drying and has the following values: saponification number 183, iodine number 87.1, fatty

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[1] Buchner's Rep. Pharm. 1864, **13,** 153.

[2] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87.**

[3] Philippine J. Sci. 1913, **8,** 59.

[4] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[5] Agr. Ledger 1907, No. 2, 13.

Composition of Tamarind Seeds (Hooper)

	Water	Protein	Fat	N-f. ext.	Fiber	Ash	P_2O_5
	%	%	%	%	%	%	%
Whole........	10.50	13.87	4.50	63.22	5.36	2.55	0.40
Decorticated...	9.35	18.06	6.60	62.88	0.66	2.45	0.55

acids 94.9 per cent melting at 46° C., and acid number 0.84. The low iodine number is not consistent with semi-drying properties. Kafuku, Hata, and Fugikawa[1] give the following values for the oil from seeds containing water 16.6, oil 3.9, and ash 2.0 per cent: specific gravity at 20°/4° 0.9273, refractive index at 20° C. 1.4750, saponification number 206.4, iodine number 110.7, acid number 8.4, and unsaponifiable matter 1.70 per cent.

Acids.—The acids of tamarind attracted the attention of early investigators. Vauquelin[2] reported *tartaric*, *citric*, *malic*, and *acetic* acids. As in the grape, the principal acid, tartaric, is combined in considerable part as potassium bitartrate which separates in crystalline form.

Sudborough and Vridhachalam,[3] who have devised a process for preparing commercial tartaric acid from the tamarind, state that the pulp contains 12 to 14 per cent of that acid, partly free and partly combined. Marsden,[4] by extracting tamarind pulp with water, fermentation, distillation of the alcohol, and evaporation in an autoclave, secured a yield of about 10 per cent of tartaric acid. Batham and Nigam[5] found that 5 samples of fresh ripe tamarind contained 30 to 41 per cent of reducing sugars and 9.5 to 12.76 per cent of tartaric acid, the higher sugar content being associated with the lower acid content. Unripe tamarinds contained little sugar or acid.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[6] reports about 0.60 per cent, dry basis, in the green fruit flesh.

Mineral Constituents.—Determinations by Chace[7] of the mineral constituents in tamarinds, containing 1.56 per cent of ash, yielded on the ash basis the results tabulated on the next page.

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[1] J. Chem. Soc. Japan 1934, **55**, 375.

[2] Ann. chim. 1790, **5**, 102.

[3] J. Indian Inst. Sci. 1920, **3**, 61.

[4] Ibid. 1923, **5**, 157.

[5] Agr. Res. Inst. Pusa 1924, Bul. **153**, 10.

[6] Philippine Agr. 1932 **21**, 53.

[7] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

CaO	MgO	P_2O_5	SO_3	SiO_2	Sand	Cl
%	%	%	%	%	%	%
0.68	2.19	4.99	1.45	15.57	2.88	0.48

CAROB

Ceratonia siliqua L.

Fr. Caroube. Sp. Algarroba. It. Carruba. Ger. Johannisbrot.

The carob tree was cultivated and highly esteemed by the Ancients. It is stated that the husks which the prodigal son ate were pods of the carob, furthermore that the locusts and wild honey on which John the Baptist subsisted were the seeds and pods of this species, hence the names St. John's bread and honey locust. Throughout the Mediterranean regions it is today cultivated in numerous varieties as food for the poorer classes and cattle. Its introduction into Florida and California bids fair to prove a success. Being rich in sugars, various syrups and fermented liquors are prepared from infusions.

MACROSCOPIC STRUCTURE.—The *trees* are polygamo-diœcious. Unlike other food legumes but like species of *Copaiva*, the *flower* has no corolla. The hermaphrodite flowers have five calyx lobes, five stamens, and above the latter a disk from the center of which arises the conical pistil with a short style and a shield-shaped stigma.

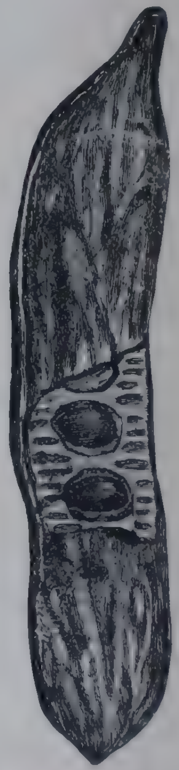

FIG. 233.—Carob. Fruit showing seeds and lateral cavities. × ½. (A.L.W.)

The *pod* (Fig. 233) is chocolate-brown, lustrous, and varies in size and number of seeds with the variety. Both the dorsal and ventral edges are grooved; the flattened sides are sunken and wrinkled. Each seed is in a cavity with a thin, yellow-brown, parchment-like lining, easily distinguished from the brown fruit flesh. A longitudinal section cut through the edges shows a row of transversely elongated cavities running on each side of the seed cavities.

The *seeds* (Fig. 233) are obovate, dark red or brown, lustrous, about 9 mm. long, and so uniform that the weight of one was taken as the goldsmith's unit, the carat. The hilum is a mere dot between the micropyle and the strophiole from which latter the raphe may be traced to the chalaza at the opposite end. It requires a sharp blow to force a knife through the dense horny, gray-white endosperm which is bisected by the narrow yellow cotyledons.

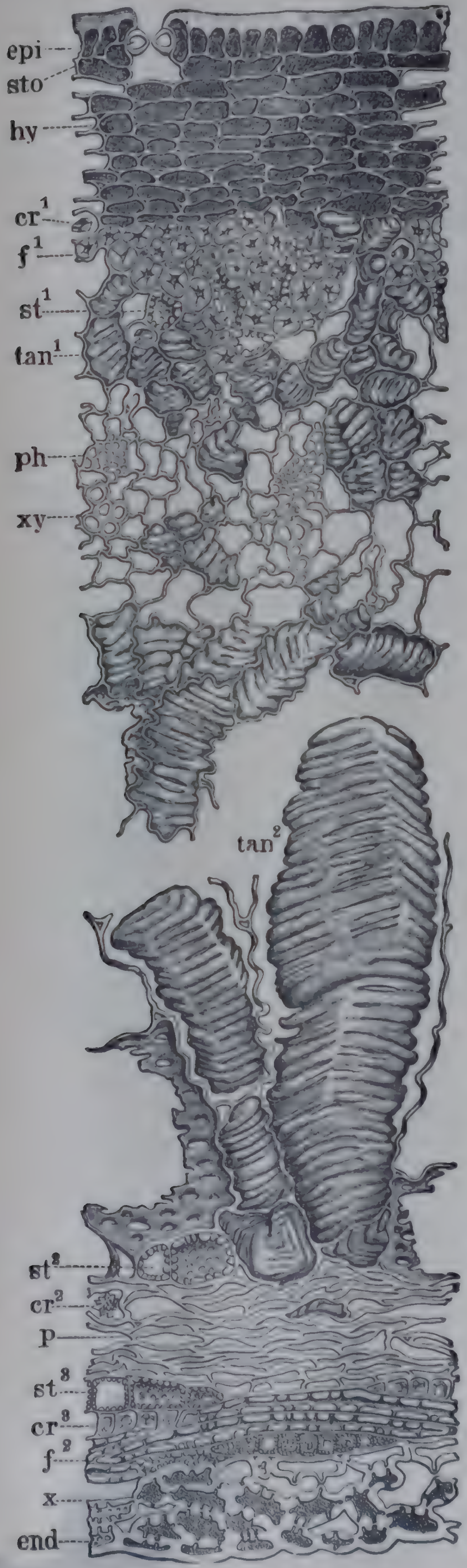

Fig. 234.—Carob. Pericarp in cross section. *epi* epicarp with *sto* sunken stoma; *hy* hypoderm; cr^1 crystal cell and st^1 stone cells accompanying f^1 bast fiber group; tan^1 small tannin cells; *ph* phloem and *xy* xylem of fibro-vascular bundle; tan^2 large tannin cells; st^2 stone cells; *p* compressed parenchyma with cr^2 rosette crystal; st^3 stone cell fiber and cr^3 crystal cell fiber accompanying f^2 bast fibers; *x* porous tissue with swollen walls passing into *end* endocarp. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE.—Flückiger[1] appears to have been the first to study the fruit. Other food histologists have been concerned with its detection as an adulterant of coffee.

Pericarp (Fig. 234).—The layers are: (1) *epicarp* (*epi*) of polygonal, sometimes porous, cells and sunken stomata (*sto*); (2) *hypoderm* (*hy*), up to ten cells thick, with brown contents; (3) *outer mesocarp*, remarkable for the tannin bodies (tan^1, tan^2), fiber groups (f^1), stone cells (st^1), crystal cells (cr^1), and bundle elements (*ph*, *xy*); (4) *inner mesocarp* of compressed cells (*p*), several thick, stone cells (st^2), and crystal rosette cells (cr^2); (5) *fiber layer* consisting of transverse fibers of the bast type (f^2), thin-walled crystal fibers (cr^3), and stone cell fibers (st^3), some containing crystals; and (6) *endocarp* including thick-walled porous cells (*x*), several thick, and an inner layer, or true endocarp (*end*), of similar cells with pores limited chiefly to the inner walls.

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[1] Pharmakognosie, Berlin, 1 Aufl. 1867, p. 585.

The *tannin bodies* (*Inklusen* of German authors) were discovered in the carob by Flückiger and have been studied by other authors.[1] Tunmann concluded that they consist of a bassorin-like substance combined with a phloroglucin-tannin compound. They occur also in the medlar and allied species, the seeds of the date, persimmon, and species of *Anona*, and in the spermoderm of the allspice. As shown in Fig. 234, the tannin bodies of the dried carob pod have wrinkles corresponding to those of the cell walls. About the bundles (tan^1) they are much smaller than in the radially elongated cells further inward where they reach the length of 500 μ (tan^2). With ferric salts they become dark green or black, with caustic soda, especially on warming, blue or violet, becoming finally brown, with safranin, a beautiful cherry red.

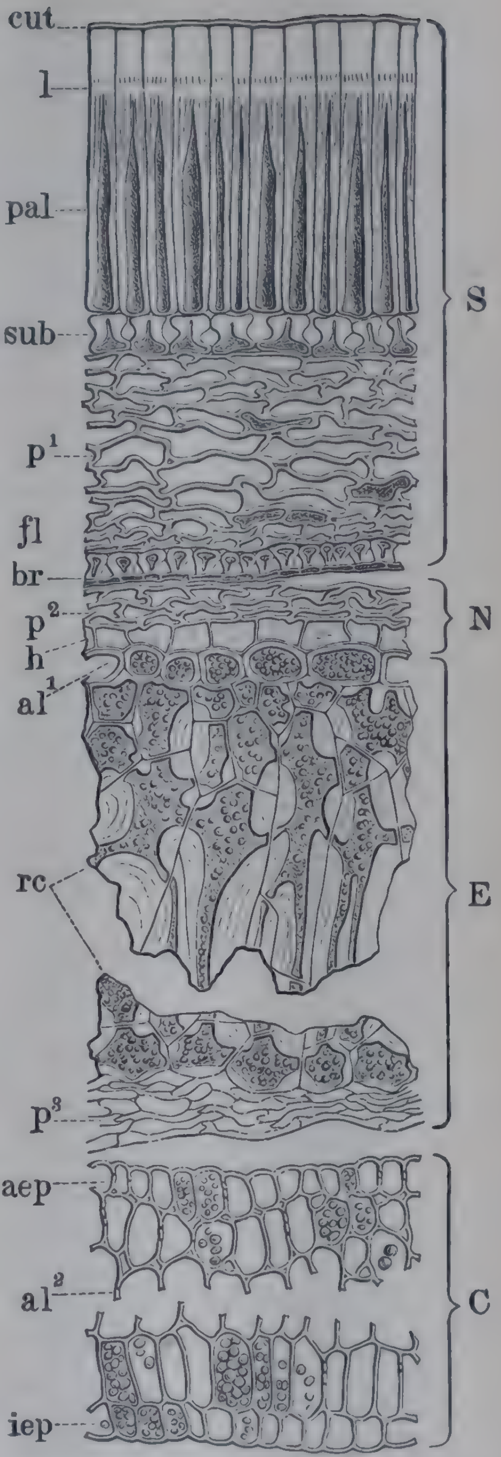

FIG. 235.—Carob. Seed in cross section. *S* spermoderm: *pal* palisade cells with *cut* cuticle and *l* light line, *sub* subepiderm, p^1 parenchyma, *fl* funnel cells, *br* brown inner epiderm. *N* perisperm: p^2 compressed cells, *h* hyaline layer. *E* endosperm: al^1 aleurone cells, *rc* thick-walled cells, p^3 parenchyma. *C* cotyledon: *aep* outer epiderm, al^2 aleurone cells, *iep* inner epiderm. × 160. (K.B.W.)

Spermoderm (Fig. 235, *S*).—Five well-differentiated layers are present: (1) *palisade cells* (*pal*), up to over 175 μ long and 20 μ broad, with a thin cuticle (*cut*) and light line (*l*) in the outer quarter which is without lumen; (2) *subepiderm* (*sub*) of spool-shaped cells, up to 35 μ high and 30 μ broad, with much-thickened outer radial walls and brown contents; (3) *parenchyma* (p^1) of thick-walled cells with small intercellular spaces and brown contents; (4) *funnel cells* (*fl*) resembling the subepidermal cells except in shape; and (5) *inner epiderm* (*br*) of thin-walled cells with brown contents.

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[1] Tunmann: Apoth. Zeit. 1913, **28**, 772; Tichomirow: Bot. Centralb. 1885, **21**, 222; Hartwich and Winckel: Arch. Pharm. 1904, **242**, 471; Hanausek: Pharm. Post. 1910, p. 1041; Haellstroem-Helsinski: B. deut. pharm. Ges. 1910, **20**, 446.

Beneath the hilum a double palisade layer, characteristic of leguminous seeds, is not strongly developed and a sclerenchyma group is lacking, but the spongy parenchyma cells are very thick-walled, with yellow contents and small intercellular spaces, and the funnel cells are rounded, forming a compound layer.

Perisperm (Fig. 235, *N*).—Although in most common legumes this coat is not evident, in the carob two distinct layers are present: (1) colorless *thick-walled cells* (p^2), longitudinally elongated, without contents; and (2) *hyaline layer* (*h*), showing radial walls on treatment with Labarraque solution.

Endosperm (Fig. 235, *E*).—This coat, commonly absent in legumes or much reduced, forms the bulk of the seed with three distinct tissues: (1) *aleurone cells* (al^1) forming a single distinct row; (2) *thick-walled cells* (*rc*), with reserve material partly in the cell walls, containing aleurone grains and brown granules; and (3) *thin-walled* parenchyma (p^3).

Embryo (Fig. 235).—The structure of the cotyledons (*C*) is characterless. The walls are of medium thickness with or without distinct pores. Beneath the inner epiderm they are palisade-shaped. Aleurone grains up to about 6 μ and fat are the visible contents.

CHIEF STRUCTURAL CHARACTERS.—Pod broad, grooved on both edges, lustrous, with rows of narrow transversely elongated cavities on both sides of seed cavities, latter with parchment-like lining. Seeds obovate, dark brown or red, lustrous, 9 mm. long, hilum at narrow end, chalaza at broad end.

Epicarp with sunken stomata; mesocarp with tannin bodies, often 500 μ, blue with sodium hydroxide; endocarp of thick-walled porous cells. Palisade cells 175 μ high, outer quarter without lumen; subepidermal cells spool-shaped; parenchyma thick-walled; funnel cells and inner epiderm with dark contents. Perisperm present. Endosperm horny, with reserve material partly in thickened walls, forming bulk of seed. Cotyledons characterless.

CHEMICAL COMPOSITION.—Both the pods and the seeds are valuable as food although the latter, being too hard even for animals to masticate, must be reduced to a powder. The chemical as well as the physical characters of the pod and seed are quite different, the former being rich in sugars but poor in proteins, the latter poor in sugars but rich in proteins and hemicelluloses. The table below has been compiled from analyses made by Woll[1] and Jaffa and Albro:[2]

COMPOSITION OF CAROB BEAN

	Samples	Water	Protein	Fat	N-f. ext.	Sugars, reducing	Sucrose	Fiber	Ash
		%	%	%	%	%	%	%	%
Woll:									
Pod and seed	1	9.99	5.26*	0.42	75.57	.....	.....	6.31	2.45
J. and A.:									
Pod and seed	8								
Min......		9.12	3.26	1.00	26.99	3.25	6.39	4.98	1.67
Max......		19.81	15.22	3.82	43.57	18.69	41.56	17.42	3.46
Aver......		**13.28**	**6.75**	**2.17**	**39.80**	**11.08**	**19.44**	**9.29**	**2.57**
Pod	17								
Min......		3.70	2.02	1.22	24.48	3.00	7.02	3.14	1.75
Max......		24.70	7.18	4.02	48.36	20.54	43.62	15.31	3.87
Aver......		**11.50**	**4.50**	**2.37**	**36.30**†	**11.24**	**23.17**	**8.78**	**2.72**
Seed	6								
Min......		8.89	14.44	1.83	55.66	.....	.....	6.90	2.32
Max......		13.63	19.69	3.06	62.54	.....	.....	8.34	3.60
Aver......		**11.74**	**16.46**	**2.50**	**58.61**	.....	.....	**7.50**	**3.18**

* Nitrogen 0.93, albuminoid (protein) nitrogen 0.71 per cent. † Starch 1 per cent.

Carbohydrates.—The analyses of Jaffa and Albro given above show well the high content of reducing sugars and sucrose in the pod. The carbohydrate material of the seeds is of a very different character, being largely in the swollen cell walls. Both microscopic examination and chemical analysis show that the seed belongs in the class with the coffee bean, the date stone, the ivory nut, and the persimmon seed. Bourquelot and Hérissey[3] found that the carbohydrates forming four-fifths of the seed consist chiefly of *mannan* and *galactan* which on hydrolysis pass into mannose and galactose and that on sprouting an enzyme is instrumental in effecting the hydrolysis, a phenomenon which Hérissey[4] makes use of in his method of preparing mannose. A similar enzyme, *seminase*, performs a like function in the sprouting of fenugreek and alfalfa seeds.

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[1] Wisconsin Agr. Exp. Sta. Rep. 1891, p. 203.

[2] California Agr. Exp. Sta. Rep. 1919, Bul. **309**, 441.

[3] Compt. rend. 1899, **129**, 391, 614; 1900, **130**, 42, 731.

[4] Ibid. 1901, **133**, 49, 302.

Enzymes.—Wagenaar[1] has studied an enzyme of the carob bean which acts on urea forming ammonium carbamate. He designates this enzyme "*semi-urease*" for the reason that it performs only half the function of an ordinary urease and does not carry the hydrolysis to completion with the formation of ammonia and carbon dioxide. See also Carbohydrates.

Minor Mineral Constituents. *Zinc.*—Seedless 6.9 mg. per kilo, fresh basis (Bertrand and Benzon).[2]

KAMANCHILE

Pithecolobium dulce Benth. = *Mimosa dulcis* Roxb. =
Inga dulcis Willd.

Fr. Tamarin de l'Inde.

The ornamental tree known in the Philippines as kamanchile or Manila tamarind is remarkable because of the spirally twisted pod and fleshy arils which are eaten by the natives. Other species yielding edible fruits or seeds are *P. Unguiscati* Benth. (tropical and subtropical America), *P. flexicaule* Coult. (southern United States and Mexico), and *P. Saman* Benth. (Mexico and northern South America).

MACROSCOPIC STRUCTURE.—The *flowers*, which are borne in dense heads, are small, white, and pubescent. This species, as well as some others of the genus, has a spiral pod, often with two complete turns. Between the seeds the pod is constricted but not septate. Both dorsal and ventral sutures are flanked by ribs.

Each *seed* is completely surrounded by a whitish, fleshy, much-convoluted aril, the whole being obovoid, 1.5 to 2 cm. long and somewhat flattened. The seed proper is anatropous, strongly flattened, up to 1.5 cm. long, dark brown, lustrous throughout, with a faint circular ridge on each side about one-third the distance to the center. Unlike the seeds of coffee cassia, tamarind, and some other legumes, there is no noticeable difference in the surface within the ridges and on the edges. The hilum is elongated, about 3 mm. long, and is located in the narrow end of the seed which lies in the axis of the pod. Aril and seed are borne on a funiculus about 1 cm. long which follows along the edge to the hilum. The spermoderm is readily removed from the seed, disclosing the bulky cotyledons and short straight radicle. Neither endosperm nor perisperm is present.

MICROSCOPIC STRUCTURE.—The **Pericarp** tissues are (1) *epicarp* of rounded cells with thick beaded walls, stomata, and occasional unicellular, blunt-pointed, warty hairs, up to 200 μ or over long, with narrow lumen; (2) *parenchyma* with fibro-vascular bundles forming the bulk of the pod; (3) *fibers* with thick walls, longitudinally arranged, forming several rows; (4) *elongated parenchyma* forming a single layer; and (5) *endocarp* of polygonal, beaded cells.

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[1] Pharm. Weekbl. 1925, **62**, 397.

[2] Bul. soc. hyg. aliment. 1928, **16**, 457.

Aril.—The tissues consist of rounded, thin-walled, characterless cells containing a small number of starch grains up to 10 μ, some in small aggregates.

Spermoderm.—The tissues, all of a brown color, are (1) *palisade cells* up to 70 μ high and 14 μ broad, the outer portion (about one-quarter) being of different structure from the remainder; (2) *subepiderm* of thick-walled, spool-shaped cells up to 15 μ high and 30 μ broad; and (3) *parenchyma*, with thick walls, forming a number of rows without differentiation into an inner epiderm.

Embryo.—The cells of the cotyledon are rounded, more or less isodiametric. They contain a small amount of starch, the grains, up to 6 μ, being entangled in a protein network.

CHIEF STRUCTURAL CHARACTERS.—Pod spiral, constricted but not septate. Aril fleshy; seed brown, flattened, with hilum in axis of pod, borne on long funiculus.

Epicarp hairs warty, unicellular, blunt-pointed; third layer of pericarp of fibers in several rows. Aril of rounded, thin-walled cells containing starch up to 10 μ. Palisade cells up to 70 μ high and 14 μ broad, the outer quarter being of different structure from the inner; subepidermal cells spool-shaped, 15 μ high and 30 μ broad. Cotyledon of rounded cells containing small starch grains in protein network.

CHEMICAL COMPOSITION.—An analysis by Adriano,[1] of the edible portion (aril) constituting 52.53 per cent of the whole pod, follows: water 78.28, protein 2.47, fat 0.34, nitrogen-free extract 17.14, fiber 1.30, and ash 0.47 per cent.

Fatty Oil of Seed.—Kesava-Menon [2] obtained from the large black seeds 18.22 per cent of yellowish oil with the following values: refractive index at 25° C. 1.4720; solidifying point 15° C.; saponification number 205.9; iodine number 56.6; Reichert-Meissl number 8.4; fatty acids 87.6 per cent, melting point 44.7° C., saponification number 198.7, iodine number 57.6, mean molecular weight 282.2; and unsaponifiable matter 1.17 per cent.

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[1] Philippine Agr. 1925, **14**, 57.

[2] J. Soc. Chem. Ind. 1910, **29**, 1428.

FRUITS OF THE OXALIS FAMILY

(Oxalidaceæ)

Carambola and bilimbi, the two species yielding fruit edible in their entirety when green, belong in the same genus and differ little in structure.

COMPARATIVE MACROSCOPIC STRUCTURE.—The fruits are five-loculed and distinctly (carambola) or indistinctly (bilimbi) five-angled. Spermoderm and cotyledons are thin, endosperm bulky.

COMPARATIVE MICROSCOPIC STRUCTURE.—Giant cells of the mesocarp often separated by chains of small cells, also crossing fibers of the endocarp are conspicuous. Aleurone grains are the visible contents of the endosperm.

COMPARATIVE CHEMICAL COMPOSITION.—The acidity is stated to be due to oxalic acid. This acid is unquestionably present as oxalates, some of which may be soluble in water, but judgment on the nature of the free acid should be reserved awaiting further study.

CARAMBOLA

Averrhoa Carambola L.

Fr. Carambole. Sp. Carombola. Ger. Karambola.

Whether a native of Malaysia, as seems probable, or of tropical America, as some have believed, the tree yielding this fruit is now grown in both regions as well as in China, India, and Hawaii. In the Philippines, according to Pratt and Del Rosario, it is known as *bilimbi*, *bilimbin*, and *balimbing*, and in Guam, according to Safford, as *bilimbines*, names which belong more appropriately to *A. Bilimbi* L.

The fruit is eaten to some extent uncooked when ripe, but is commonly preserved or pickled when green. Chinese mixed pickles, tinned at Hongkong, often contain the green but nearly if not quite full-sized fruit. Both carambola and bilimbi serve to remove iron and ink stains and to clean brass.

MACROSCOPIC STRUCTURE.—As in the bilimbi, the *flowers* are purplish red, normally with five sepals, petals, perfect stamens, abortive stamens, and ovary cells. When ripe the *fruit* (Fig. 236) varies up to

12 cm. in length and has as many angled ribs as there are locules, the cross section being star-shaped. The *seeds* are anatropous, about 1 cm. long, brown, flattened, and pointed at both ends, two occurring in each locule. A thin spermoderm encloses a bulky endosperm embedded in which is the straight central embryo with broad, thin cotyledons. A small caruncle occurs at the base of the seed.

MICROSCOPIC STRUCTURE. Pericap (Fig. 237).—The tissues are (1) *epicarp* (*epi*) of isodiametric cells with marked division into daughter cells, each containing a single small oxalate crystal (*cr*), also numerous stomata (*sto*); (2) *hypoderm* (*hy*) with several rows of small cells containing chlorophyl grains; (3) *outer mesocarp* consisting of giant cells (*g*), up to 1 mm. in diameter, separated by chains of smaller cells (*mes*), and delicate fibro-vascular bundles, accompanied by crystal-bearing cells; (4) *inner mesocarp* (*p*) of spongy parenchyma; and (5) *endocarp* (*end*) of crossing sclerenchyma fibers interspersed with occasional cells containing single crystals.

Spermoderm (Fig. 238, *S*).—When mature and usually at the stage used for pickling, the following layers are evident: (1) *outer epiderm* (*aep*) of colorless, radially elongated cells with thin walls excepting the outer which is very thick and shows mucilaginous striations; (2) *spongy parenchyma* (*p*) forming a broad band; (3) *palisade cells* (*pal*) with deep brown walls, the lumen being evident only at the outer end; (4) *reticulated cells* (*ret*), longitudinally elongated, also with brown walls and, as seen in surface view, diagonal thickenings; and (5) *inner epiderm* (*iep*) of collapsed, brown, thin-walled cells sometimes two thick.

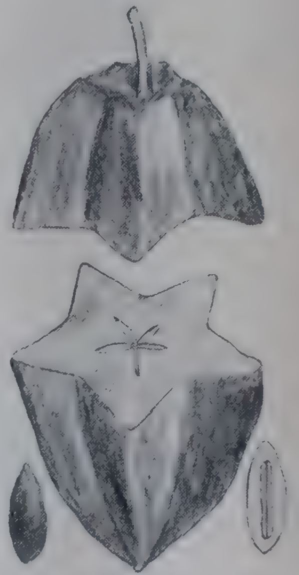

FIG. 236.—Carambola. Fruit, × ½. Seed, whole, × 1; in cross section, × 2. (A.L.W.)

Endosperm (Fig. 238, *E*).—The usually isodiametric cells contain small aleurone grains, some of the larger ones with evident crystalloids.

Embryo.—The cells of the *cotyledons* (Fig. 238, *C*) are thinner-walled and the aleurone grains contained in them smaller even than those of the endosperm.

CHIEF STRUCTURAL CHARACTERS.—Fruit five-angled, five-loculed. Seeds brown, flattened, pointed at both ends; spermoderm and cotyledons thin; endosperm bulky.

Mesocarp with giant cells and chains of smaller cells; endocarp with crossing fibers. Outer epiderm of spermoderm of radially elongated cells with thick outer walls; third layer of palisade cells with visible lumens only in outer ends; fourth layer of diagonally reticulated cells. Endosperm and cotyledons contain small aleurone grains.

CHEMICAL COMPOSITION.—Analyses have been made by Pratt and Del Rosario [1] and by Adriano [2] of samples of carambola (balimbing) grown in the Philippines and by Thompson [3] of samples designated sweet and sour grown in Hawaii. Pratt and Del Rosario [1] and Adriano, Monahan, and Barros [4] analyzed bilimbi fruit from the Philippines. Both fruits were green and edible without waste. Pratt and Del Rosario state that the strong acidity of both fruits is due to *oxalic acid* and that these fruits are the only ones containing that acid; the acidity is accordingly here given in terms of oxalic acid although with some misgivings. Accepting the result given for bilimbi, which is on the assumption that all the acid is oxalic in the free form, about 250

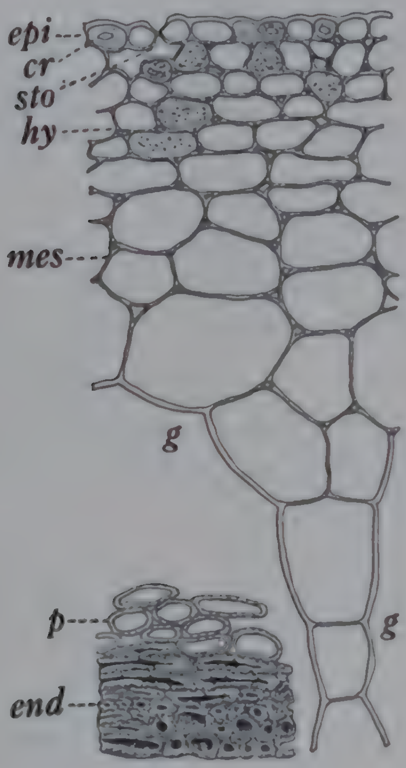

Fig. 237.

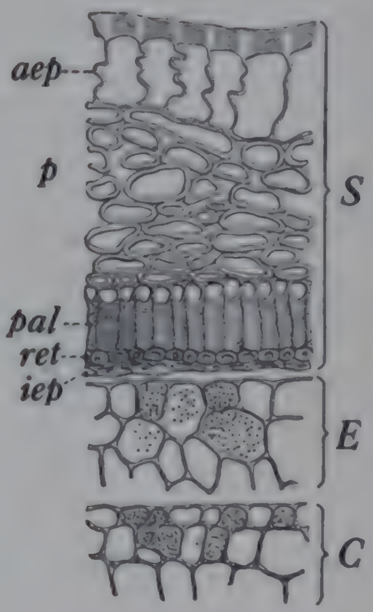

Fig. 238.

Fig. 237.—Carambola. Pericarp in cross section. *epi* epicarp with *sto* stoma; *cr* crystal; *hy* hypoderm; *mes* outer mesocarp with chain of cells between *g* giant cells; *p* spongy parenchyma; *end* endocarp. × 160. (K.B.W.)

Fig. 238.—Carambola. Seed in cross section. *S* spermoderm: *aep* outer epiderm, *p* spongy parenchyma, *pal* palisade cells, *ret* reticulated cells, *iep* inner epiderm. *E* outer endosperm with aleurone grains. *C* cotyledon. × 160. (K.B.W.)

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[1] Philippine J. Sci. 1913, **8**, 59.

[2] Philippine Agr. 1925, **14**, 57.

[3] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[4] Philippine Agr. 1929, **18**, 119.

grams of the fruit would contain a lethal dose, namely 4 grams. A similar case is that of rhubarb stalks and leaves.

COMPOSITION OF CARAMBOLA AND BILIMBI FRUITS

	Weight	Solids, total	Solids, insol.	Protein	Fat	Acids as oxalic	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	%	cc.
Carambola:											
Philippine											
P. and Del R.	33	9.4	2.6	0.84	....	0.31	2.64	0.00	....	0.51	47
Adriano	..	6.09	....	0.24	0.74	....	....	....	0.61	0.42	..
Hawaiian											
Sweet†	..	8.22	3.13	0.72	0.76	1.01	3.40	0.00	1.24	0.42	..
Sour†	..	8.69	2.84	....	0.31	0.40	5.25	0.16	0.99	0.41	..
Bilimbi:											
Philippine											
P. and Del R.	16	5.3	1.6	0.61	....	1.55	2.21	0.00	....	0.41	39
A. M. and B.	..	5.14	....	0.68	1.39	....	....	....	0.61	0.36	..

* Cc. $N/10$ acid per 100 grams fruit. † Names are not in accord with the analysis.

BILIMBI

Averrhoa Bilimbi L.

Fr. Balimba. Ger. Blimbing.

In the Philippines this fruit is known as *camias*. Like the carambola, it is strongly acid and is much used for pickles and preserves.

MACROSCOPIC STRUCTURE.—*Flower* and *fruit* resemble those of carambola but the perfect stamens number ten and the fruit is smaller, cucumber-shaped, with five indistinct rounded angles.

MICROSCOPIC STRUCTURE.—Long (up to 400 μ), thick-walled hairs occur on the *epicarp*. Otherwise the **Pericarp** resembles that of carambola.

The cells of the **Spermoderm,** at the immature stage of the specimens examined, lack marked radial elongation in the *outer epiderm* and the *third layer*; each cell of the latter, however, contains a small single crystal. Possibly at a more mature stage the structure agrees more closely with that of carambola.

Endosperm and **Embryo.**—As in carambola.

CHEMICAL COMPOSITION.—See Carambola.

FRUITS OF THE RUE FAMILY

(*Rutaceæ*)

The citrous fruits and one other species, the white sapota, represent this family.

CITROUS FRUITS

All of the species described herewith belong to the genus *Citrus* except the kumquats, which are now classed under *Fortunella.*

COMPARATIVE MACROSCOPIC STRUCTURE.—The *fruit* is a type of berry known as hesperidium. Each consists of (1) rind (epicarp, hypoderm, and most of the mesocarp) and (2) segments (inner mesocarp, endocarp with vesicles, and seeds).

Pericarp.—The *epicarp* varies from orange-red in the tangerine to yellow in the lemon and grapefruit and green-yellow in the lime. In the blood orange it is suffused with blotches of cherry red. *Hypoderm* and juice in the vesicles conform more or less closely in color to that of the epicarp. Small round elevations (about 1 mm.) on the epicarp occur over the oil cavities. On drying, these become depressions.

Beneath the hypoderm in the outer mesocarp is the zone of *volatile oil cavities* which are visible to the naked eye in sections. The greater part of the rind is *spongy tissue* of the mesocarp. In the king orange, the tangerine, and the mandarin the segments are loosely attached to each other and to the rind and a marked axial cavity is present; in the other fruits all the parts are closely united and there is no marked axial cavity although the rind, especially of the orange, may be removed with more or less ease, the splitting taking place through the inner mesocarp.

The transparent membrane on all sides of the detached segments consists of *inner mesocarp* and *endocarp.* Attached to the inner surface of the latter by threads are the *vesicles* which, although having the appearance of sacs, consist of cellular tissues.

The *seeds* (if present) are borne on the central axis. They are irregularly spindle-shaped, often beaked, with a slimy, leathery, cream-colored *outer spermoderm* readily separating from the *inner spermoderm* which is brown in most fruits except the king orange, tangerine, and mandarin where it may be green. The *perisperm* is reduced to a mere membrane and the *endosperm* to a thin coat. Often the seeds are polyembryonic, the number of embryos reaching as high as eight. The fleshy *cotyledons* are white except in the king orange, tangerine, mandarin, and kumquat, where they are green.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—In all the species, the cell structure, except that of the vesicles, is practically the same as are also the cell contents except the color of the *chromatophores* and *juice* of the epicarp, hypoderm, and vesicles which varies from yellow to orange-red. In blood-colored fruits the red color is in solution.

The cells of the *epicarp* and *hypoderm* are polygonal, the former being interspersed with raised stomata. Oval lysigenic *volatile oil cavities* occur in a zone of the outer mesocarp. Many of the mesocarp cells about the oil cavities contain single crystals of *calcium oxalate* and some of them rosettes of needle-shaped crystals of *hesperidin.* Spongy parenchyma with fibro-vascular bundles forms the white *mesocarp* tissue through the inner part of which the rind separates. Transversely elongated cells or *cross cells* and small crystal cells adjoin the *endocarp,* which also consists of transversely elongated cells.

The *vesicles* have an epiderm of longitudinally elongated cells, some of which in the lemon, the lime, and the grapefruit have sclerenchymatized and strongly porous walls. Immediately beneath the epiderm the cells are transversely elongated; further inward they are mostly isodiametric, some containing single crystals of calcium oxalate.

Cytological studies by Dufrenoy[1] show that natural coloring of the fruit is concomitant with the translocation of starch from chloroplasts in cells of the three upper layers of the peel. As the starch disappears, fat bodies develop in the chloroplasts and the orange pigment goes into solution in the fat bodies inside the chloroplasts.

Spermoderm.—The layers are (1) *outer epiderm* of beaked cells, (2) *parenchyma,* (3) layer with *crystal cells,* and (4) *inner epiderm* of brown or greenish, longitudinally elongated cells.

The cells of the *outer epiderm* are flattened in planes radiating from the axis of the seed, hence in cross section they appear to be radially elongated and in surface view longitudinally elongated. The radial walls are sclerenchymatized and porous, ending in beaks which extend into the thick mucilaginous part of the outer walls. The fruits fall into four groups according to the nature of these cells as follows:

Group 1.—Beaks long, present only at ends of cells; cells up to 400 μ in radial diameter; double walls narrower than lumen. Common and bitter orange, king orange, mandarin, tangerine.

Group 2.—Beaks numerous, short, uniform in length, in lime somewhat longer at ends of cell, cells up to 250 μ in radial diameter; double walls broader than lumen. Lemon, lime.

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[1] J. Agr. Res. 1929, **38**, 411.

Group 3.—Intermediate between 1 and 2. End beaks very long, occasional short beaks between end ones; ratio of walls to lumen variable. Grapefruit.

Group 4.—Beaks along whole length of cell; long, branching, jagged, double walls usually broader than lumen. Kumquat.

Perisperm.—A thin zone of collapsed cells.

Endosperm.—A double or triple layer of aleurone cells with an inner zone of collapsed cells.

Embryo.—The contents are small aleurone grains with globoids.

COMPARATIVE CHEMICAL COMPOSITION.—Although in most fruits *reducing sugars* exceed *sucrose*, in citrous fruits the sucrose often equals or exceeds the reducing sugar. A still more remarkable ratio is that of acids to total sugars. Some fruits such as the lemon and lime are characterized not merely by high acidity but also low sugar content, whereas the reverse is true of sweet fruits including the sweet orange and lemon. In other words, high acidity and high sugar content or low acidity and low sugar content do not occur, so far as observed, in the same fruit.

It is commonly assumed that the acid of all citrous fruits is *citric acid*, but there is evidence that a small amount of *malic acid* is also present.

The outer rind yields volatile oil (See Volume III) and the white rind or albedo is a promising source of pectin.

Naringin occurs in the grapefruit and *hesperidin* in other species, the location of both glucosides, according to Traub, Gaddum, Camp, and Stahl,[1] being chiefly in the inner peel, veins, and walls of the locules. The bitter taste that develops in the juice on aging is attributed to glucosides formed by the action of enzymes.

Odorous constituents of the juice are considered under Orange.

Rounded orange chromatophores occur in the orange and tangerine. The color of the grapefruit suggests a preponderance of xanthophyl or the absence of carotene.

ORANGE

Citrus sinensis Osbeck = *C. Aurantium* var. *sinensis* Engl. =
C. Aurantium Risso.

Fr. Orange douce. Sp. China. It. Arancio dolce. Ger. Apfelsine.

The common orange appears to have originated in southeastern Asia and although formerly considered a variety of the bitter orange

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[1] Plant Physiol. 1933, **8**, 35.

(*C. Aurantium* L.) is now classed as a separate species. Since ancient times the orange has been one of the principal fruits of the Mediterranean region, India, and China. In England, Germany, and other temperate countries, before the days of rapid transportation, oranges were grown under glass. In Florida succession is secured by cultivation of several varieties supplying the northern market with fruit until late Winter or Spring when the Washington navel orange, a seedless variety originated in Brazil, which is not suited to conditions in Florida, is shipped from California in large quantities. According to Shamel,[1] this latter variety is seedless because the flowers produce no pollen. Of the numerous other varieties mention may be made of the Valencia Late, introduced into both Florida and California from the Azores.

Surplus fruit and culls are now used at or near the producing centers for the manufacture of orange juice, marmalade (the bitter orange is preferred), candied peel, and orange oil. Orange juice shipped frozen in small paraffin paper containers provides the consumer with a convenient and economical substitute for the freshly pressed juice.

MACROSCOPIC STRUCTURE.—Orange *flowers* are sweet scented with inconspicuous calyx, five white petals, numerous stamens in groups more or less united at the base, and six- to thirteen-celled ovary borne on a disk and surmounted by a style about the length of the stamens.

The *fruit* consists of (1) a thick rind with an orange-colored epicarp and hypoderm and a white spongy mesocarp and (2) a variable number of segments, loosely united with each other and the rind, filled with club-shaped juicy vesicles (emergences), borne on the inner surface of the thin outer skin (endocarp), and the seeds. On the surface are numerous rounded elevations, about 1 mm. in diameter, beneath which are the volatile oil cavities.

The anatropous *seeds* are borne on the central placentæ. They are slimy, veined, more or less beaked and flattened, with the raphe in a keel-like edge. The outer white, leathery spermoderm readily separates from a thinner light buff inner coat consisting of inner spermoderm united with perisperm and endosperm. The seed is often polyembryonic, containing as many as eight embryos, some of which are much reduced in size and are not capable of sprouting.

Navel oranges are seedless and have a second small fruit at the end, usually partly protruding from within the rind of the main fruit, also sometimes the segments of a third fruit in the center. In the blood orange the vesicles and often the rind are suffused with red.

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[1] Cal. Citrogr. 1918, **3**, 204.

MICROSCOPIC STRUCTURE.—Hanausek[1] was a pioneer in the study of the orange and lemon. Studies of the immature orange reported by pharmacognocists are not adequate for the understanding of the ripe fruit.

Pericarp (Figs. 239, 240, 241, and 242).—Six layers are present, the outer three and most of the fourth being in the rind, as follows: (1) *epicarp* (*epi*) of small, polygonal cells and stomata; (2) *hypoderm* (*hy*) of small polygonal cells, some with oxalate crystals (*cr*); (3) *oil cavity zone* (*ol*), the ground tissue consisting of large, porous, thick-walled cells, some of which contain a rosette of needle-shaped hesperidin crystals (*he*), and smaller cells with the wall on one side much thickened and clasping an oxalate crystal; (4) *spongy parenchyma* (*mes, mes*^{1}), forming the bulk of the rind and the loose tissue about the segments, through which run fibro-vascular bundles; (5) *cross cells* (*mes*^{2}), with thick porous walls, interspersed with small crystal cells; and (6) *endocarp* (*end*) of elongated cells similar to the last but with thinner, occasionally sclerenchymatized walls, from among which spring the vesicles.

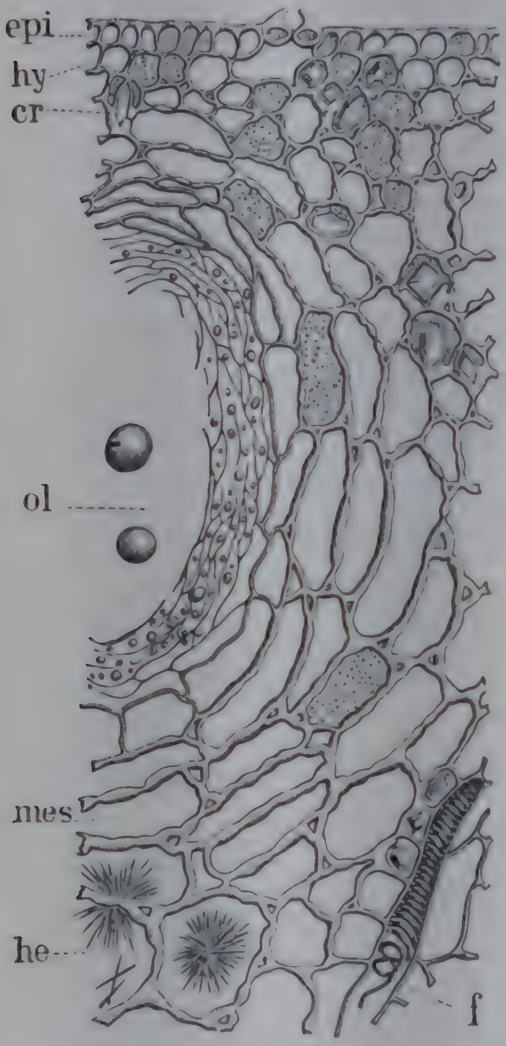

FIG. 239.

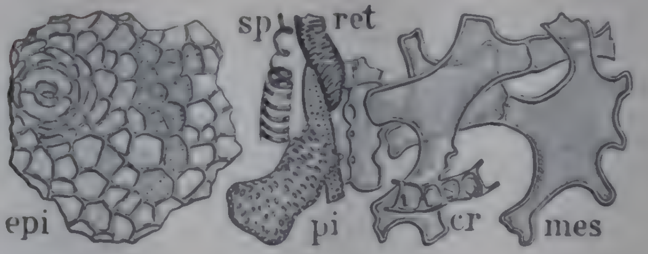

FIG. 240.

FIG. 239.—Orange. Outer rind in cross section. *epi* epicarp with stoma; *hy* hypoderm; *cr* oxalate crystals; *mes* outer mesocarp with *ol* oil cavity; *he* hesperidin crystals; *fv* fibro-vascular bundle. × 160. (K.B.W.)

FIG. 240.—Orange Elements of rind in surface view. *epi* epicarp with stoma and cells containing chromatophores; *sp* spiral, *ret* reticulated, and *pi* pitted vessels; *mes* outer spongy mesocarp; *cr* oxalate crystals. × 160. (K.B.W.)

Orange *chromatophores* occur in both epicarp and hypoderm.

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[1] Nahr.-Genussm. Kassel, 1884, p. 192.

Lysigenic *volatile oil cavities* are characteristic of the rind. They are oval, up to 1 mm. in diameter, and as seen in cross section (Fig. 239, *ol*) are lined by the thin-walled secretion cells. About the cavities the ground tissue cells of the outer mesocarp are concentrically arranged.

Tunmann,[1] also Tschirch and Oesterle,[2] found that *hesperidin* is formed early in the development of the fruit. Hall[3] has shown that the crystals on the endocarp of frozen oranges are hesperidin and also finds evidence in the endocarp of other related substances both free and in combination with glucose.

The *fibro-vascular bundles* (Fig. 240) contain spiral (*sp*), reticulated (*ret*), and pitted (*pi*) vessels and crystal fibers.

The *vesicles* (Fig. 242), distended with juice, are the only part of the fruit of appreciable value as food. Each is an emergence, not a sac, made up of numerous cells forming a club- or spindle-shaped body on a thread-like stem. This stem is long or short, accommodating itself to the space between surrounding vesicles. The cells are in three zones: (1) *epiderm* (*ep*) of cells elongated in the direction of the axis over the body and stem but isodiametric and with sinuous walls at the apex, (2) *subepiderm* (p^1) of large transversely elongated cells, and (3) *central parenchyma* (p^2) of large, rounded, thin-walled cells interspersed with smaller isodiametric cells containing single oxalate crystals. All three

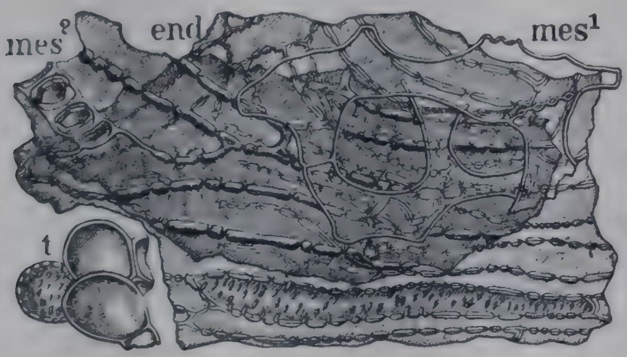

FIG. 241.

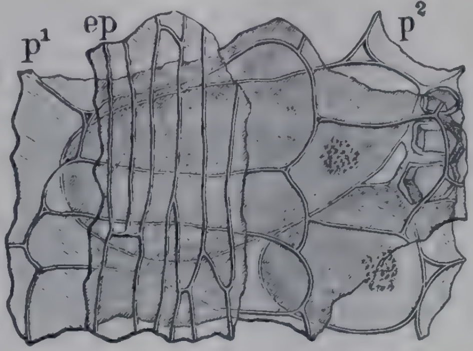

FIG. 242.

FIG. 241.—Orange. Elements of skin about edible pulp in surface view. *mes*^{1} spongy mesocarp; *mes*^{2} porous inner mesocarp and crystal cells; *end* endocarp; *t* cells from tip of abortive vesicle. × 160. (K.B.W.)

FIG. 242.—Orange. Elements of large vesicle in surface view. *ep* epiderm; p^1 outer parenchyma; p^2 loose parenchyma showing chromatophores and crystals. × 160. (K.B.W.)

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[1] Pflanzenmikrochemie, Berlin, 1913.

[2] Anat. Atlas, Leipzig, 1900, p. 302.

[3] J. Amer. Chem. Soc. 1925, 47, 1191.

kinds of cells contain chromatophores, and none, as in grapefruit and lemon, has sclerenchymatized walls.

Strikingly different are the abortive vesicles which consist of a head of rounded cells, with thickened and, at the tip, occasionally sclerenchymatized and porous walls, on a very short stalk.

Spermoderm (Fig. 243, *S*; Fig. 244).—There are four layers: (1) *outer epiderm* (*aep*) of narrow, longitudinally and radially elongated, porous cells with thickened mucilaginous outer walls in which the sclerenchymatized radial walls end as beaks; (2) *parenchyma* (*p*) of thin-walled, indistinctly porous, collapsed cells; (3) *crystal cells* (*cr*), interspersed with empty cells, forming a single layer; and (4) *inner epiderm* (*iep*) of longitudinally elongated, cuticularized, thin-walled cells with brown contents.

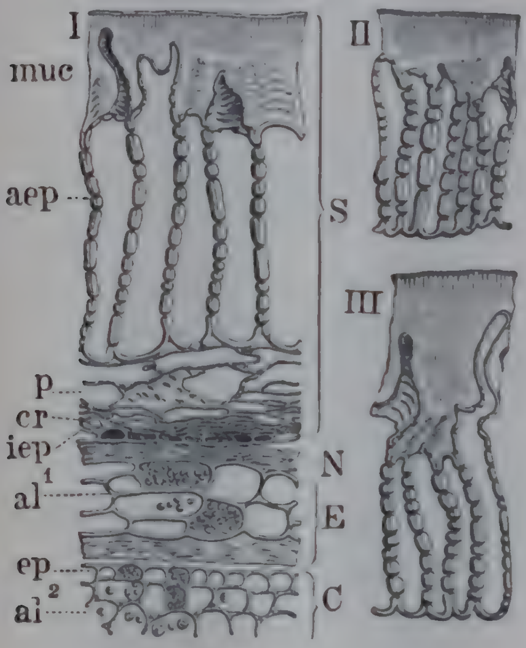

FIG. 243.

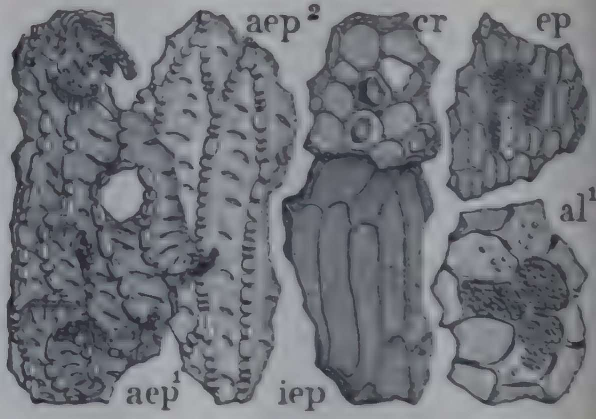

FIG. 244.

FIG. 243.—Citrous Fruits. Seeds in cross section. I Orange. *S* spermoderm: *aep* outer epiderm with *muc* mucilaginous outer wall, *p* parenchyma, *cr* crystal layer, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al*¹ aleurone cells. *C* cotyledon: *ep* outer epiderm, *al*² aleurone grains. II Lemon. Outer epiderm of spermoderm. III Grapefruit. Outer epiderm of spermoderm. × 160. (K.B.W.)

FIG. 244.—Orange. Elements of seed in surface view. Spermoderm: *aep*¹ outer and *aep*² inner wall of outer epiderm, *cr* crystal layer, *iep* inner epiderm. Endosperm: *al*¹ aleurone cells. Cotyledon: *ep* outer epiderm. × 160. (K.B.W.)

The *outer epiderm* in cross section is palisade-like, the sclerenchymatized portion varying up to 400 μ in height (shorter in lemon and grapefruit) with lumen broader (in grapefruit often and in lemon and kumquat usually narrower) than the beaded radial walls. The mucilagous outer wall shows striations which are longitudinal in the outer art and transverse in the inner. Surface preparations show that the eaks occur at each end of the cell, rarely between (in grapefruit, lemon, nd kumquat all along the cell), also that they are never as long as the ell proper (in grapefruit often and in kumquat occasionally as long s the cell).

Perisperm (Fig. 243, *N*).—This is reduced to a structureless layer f obliterated cells.

Endosperm (Fig. 243, *E*; Fig. 244).—This usually consists of a louble or triple layer of *aleurone cells* (al^1) with minute aleurone grains, within which is a tissue of collapsed empty cells.

Embryo.—The cells of the *cotyledon* (Fig. 243, *C*) are small, thin-walled, and contain aleurone grains (al^2), up to 10 μ, with one or more globoids. In the outer epiderm (Fig. 244, *ep*) the cells are longitudinally elongated, elsewhere isodiametric.

Chief Structural Characters.—Fruit globular; epicarp with elevations over oil cavities; epicarp, hypoderm, and vesicles with orange (in blood orange red) contents; segments up to thirteen adherent to rind. Seeds variable in number and number of embryos. Navel variety with auxiliary fruit, seedless.

Epicarp with raised stomata; hypoderm cells small, polygonal; ground tissue of oil cavity zone with large, thick-walled cells, often containing single oxalate crystals or rosettes of needle-shaped hesperidin crystals; bulk of rind spongy parenchyma; cells of endocarp and adjacent layer tangentially elongated; epiderm of vesicles of elongated, thin-walled cells. Spermoderm with outer epidermal cells beaked only at ends, lumen broader than radial double wall. Perisperm compressed. Endosperm with several layers of aleurone cells. Cotyledons containing aleurone grains and fat.

CHEMICAL COMPOSITION.—Analyses of 75 samples of California oranges, carried out by Colby and Dyer [1] and by Colby,[2] of 5 samples of sweet and 4 samples of bitter Sicilian oranges by Danesi and Boschi,[3] and of 60 samples of Philippine oranges by Wells, Agcaoili, and Orosa [4] are summarized on the following page. Water, protein, and ash were determined in only about half and sucrose in about one-third of the California samples.

---

[1] California Agr. Exp. Sta. Rep. 1890, p. 106.

[2] Ibid. Rep. 1891/2, p. 99; 1892/4, pp. 240 and 253; 1894/5, p. 172; 1895/7, p. 163.

[3] Staz. sper. agr. ital. 1895, **28**, 699.

[4] Philippine J. Sci. 1925, **28**, 453.

COMPOSITION OF CALIFORNIA, SICILIAN, AND PHILIPPINE ORANGES

	Fruit							Juice				
	Weight	Peel	Seed	Marc	Water	Protein	Ash	Vol.	Solids	Citric acid	Sugars, total	Sucrose
	g.	%	%	%	%	%	%	cc.	%	%	%	%
California:												
Navel												
Min.....	184	17	0	23	84.90	0.75	0.37	60	10.70	0.66	8.00	3.24
Max.....	680	36	0	41	88.19	1.54	0.56	215	15.20	1.68	13.10	6.09
St. Michaels												
Min.....	116	13	1	23	83.69	1.06	0.32	50	10.22	0.84	7.90	2.77
Max.....	179	24	2	34	89.39	1.42	0.56	90	14.25	1.55	12.20	6.52
Medit. sweet												
Min.....	124	14	0	20	82.17	0.91	0.41	55	9.80	0.92	7.65	4.00
Max.....	250	35	3	32	88.57	1.41	0.53	98	13.88	1.72	10.78	5.12
Blood												
Min.....	118	24	1	22	84.00	0.75	0.33	43	11.90	1.02	8.80	4.22
Max.....	203	37	1	30	86.87	1.68	0.59	88	15.40	2.04	13.00	5.85
All var.												
Min.....	104	13	0	18	78.71	0.69	0.29	25	9.80	0.64	6.40	2.77
Max.....	680	49	3	41	89.39	1.68	0.71	215	16.45	2.20	14.70	6.56
Sicilian:								%				
Sweet												
Min.....	120	27*	1	16	77.52†	....	....	43	9.38	1.78	2.23‡	....
Max.....	137	34*	2	23	83.78†	....	....	51	13.27	2.56	2.66‡	....
Bitter												
Min.....	91	27§	5	23	77.90†	....	....	27	9.28	2.35	0.80‡	....
Max.....	144	46§	7	31	88.30†	....	....	37	11.92	6.20	1.86‡	....
Philippine:												
Min.....	104	16	0	17	89.66	....	....	35	7.14	0.52	1.22‡	1.72
Max.....	384	40	5	42	92.86	....	....	56	10.34	2.96	4.44‡	4.85

* Volatile oil in peel 1.17 to 1.91%. † In fruit flesh. ‡ Reducing sugar. § Volatile oil in peel 1.06 to 1.35%.

Summaries of 7 analyses of Cuban oranges by Chace, Tolman, and Munson [1] and of 4 analyses of Hawaiian oranges by Thompson [2] appear below:

COMPOSITION OF EDIBLE PART OF CUBAN AND HAWAIIAN ORANGES

	Weight	Edible part in fruit	Water	Solids, insol.	Protein	Fat	Citric acid	Sugars, total	Sucrose	Fiber	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	%	%	%
Cuban:												
Min....	118	59	85.19	0.56	0.57	....	0.21	5.58	0.00	....	0.35	0.35
Max...	296	83	88.62	2.70	0.72	....	2.65	9.74	5.29	....	0.57	0.45
Hawaiian:												
Min....	...	69	87.85	2.16	0.68	0.30	0.98	5.90	2.83	0.48	0.35	....
Max...	...	72	90.44	3.01	0.83	0.45	4.91	7.24	3.81	3.66	0.51	....

* As potassium carbonate.

---

[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

Composition of Ends and Middle.—Sutherst[1] gives the following results:

	Citric acid	Invert sugar	Sucrose
	%	%	%
Stem end	2.57	3.25	4.73
Middle	2.61	3.92	5.45
Navel end	2.06	4.30	6.02

Composition of Parts.—Separate analyses of the different parts of Sicilian oranges have been made by Oliveri and Guerrieri.[2] Although the statement of the results is somewhat different from that followed in the United States, the figures permit of recalculation as shown below. The low fat content of the seed indicates abortion and the low sugar content of the juice suggests that only reducing sugars were determined:

COMPOSITION OF PARTS OF ORANGE (OLIVERI AND GUERRIERI)

	Water	Protein	Fat	N-f. ext.	Acids	Sugars	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Peel (35%)	73.52	1.73	2.09*	21.98†	....	....	....	....	0.68
Juice (44%)	90.35	0.40	....	8.94	1.35‡	2.51	....	....	0.31
Marc (18%)	77.66	1.69	1.32	14.73	....	....	0.26	3.92	0.42
Seed (3%)	58.75	13.35	0.89	26.11†	....	....	....	....	0.90

* Volatile oil. † Includes fiber. ‡ As citric.

Serger[3] also analyzed the separate parts of the orange, the results being as shown in the following table:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Peel (about 25%)	69.94	1.47	0.61	12.71	13.98	1.26
Peel, pure	61.70	1.14	0.88	14.44	10.65	1.13
Marc	68.34	1.93	0.22	10.30	7.75	1.46
Seed (about 1.5%)	11.59	14.36	20.04	25.83	25.01	3.17
Seed, pure	12.50	16.64	24.75	17.62	15.60	2.89
Seed, skin	7.94	5.26	1.20	33.54	47.75	4.31

---

[1] Calif. Cult. **26**, 612; Chem. Abs. 1912, **6**, 1642.

[2] Staz. sper. agr. ital. 1895, **28**, 287.

[3] Chem. Ztg. 1917, **41**, 517.

In the seeds of Italian oranges, ripened by storage and analyzed January 1, Scurti and de Plato[1] found in terms of the dry material the results given below:

Composition of Orange Seeds (Scurti and de Plato)

	Protein	Fat	Pentosans	Cellulose	Ash
	%	%	%	%	%
Sweet	15.31	39.56	7.93	15.62	3.47
Common	8.44	42.09	7.23	17.80	3.31
Bitter	17.18	42.78	8.15	17.74	2.73

Kobayashi[2] gives analyses of the seeds of three varieties designated *Sinensis* Engl. (I), *Fortunella Japonica* Swingle (II), and *Junos* Mak. (III) as tabulated below:

	Water	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
I (yield 2%)	44.67	10.68	19.52	18.70	4.68	1.75
II (yield 3.7%)	39.06	8.66	25.50	17.25	7.23	2.30
III (yield 9.5%)	10.60	14.94	21.88	44.63	5.41	2.53

Inheritance of Composition.—Analyses of 18 strains of Washington Navel orange by Chace and Church[3] show that the amount of constituents, notably peel, oil, insoluble solids, and acid, as well as physical characters of the fruit are inheritable. Strains with smooth skin contain low percentages of oil and as a rule those with heavy peel have a low specific gravity, although modified by other factors. Results on the Washington and Thomson strains tabulated herewith suffice to show the general trend.

Changes in Composition during Growth.—It has been shown by Bigelow and Gore[4] that the fruit flesh increases more rapidly than the skin and that the acid and cell wall tissue of the fruit flesh are formed early and remain nearly unchanged in amount during further development, while the sugars increase gradually, reducing sugars and sucrose existing in about equal amount.

---

[1] Staz. sper. agr. ital. 1908, **41**, 433.

[2] J. Chem. Ind. Japan 1918, **21**, 1235.

[3] U. S. Dept. Agr. 1930, Tech. Bul. **163**.

[4] J. Am. Chem. Soc. 1907, **29**, 767.

Composition of Oranges from Parent Tree and Offspring (Chace and Church)

	Whole Fruit			Flesh, insol. solids	Juice			
	Sp. gr.	Peel	Oil		Soluble solids	Sugars	Acid	Soluble solids: acid
		%	%	%	%	%	%	Ratio
Washington:								
Parent......	0.911	31.1	0.70	3.15	14.05	10.36	1.02	14.0
Offspring....	0.892	34.0	0.60	2.72	12.84	9.14	1.09	12.2
Thomson:								
Parent......	0.903	30.1	0.35	3.51	14.27	10.98	0.83	17.5
Offspring....	0.889	33.7	0.31	2.93	13.29	9.71	0.92	14.8

Changes in Composition during Ripening and Storage.—In experiments by Bigelow and Gore,[1] storage at room temperature resulted in a slight loss of acid and total sugars but a marked increase of reducing sugars at the expense of sucrose. The losses were due to respiration. The marc remained practically unchanged. Scurti and de Plato[2] examined three types of Italian oranges, sweet (*dulci*), common (*communi*), and bitter (*amari*), at intervals of two weeks beginning November 16 and ending June 1. Only the results at the beginning and the end of the experiment are given below:

	Solids	Nitrogen			Acids as citric	Sugars, reducing	Sucrose	Ash
		Total	Lead-tannin precipitate	Lead-tannin filtrate				
	%	%	%	%	%	%	%	%
Sweet:								
Green...	9.79	0.1008	0.0518	0.0490	0.11	6.13	0.57	0.42
Ripened.	10.66	0.0705	0.0259	0.0446	0.15	7.95	1.05	0.36
Common:								
Green...	8.66	0.0812	0.0345	0.0467	2.14	2.38	2.76	0.41
Ripened.	10.35	0.0706	0.0218	0.0488	1.95	3.33	3.13	0.34
Bitter:								
Green...	11.14	0.1090	0.0628	0.0462	6.16	1.56	0.94	0.40
Ripened.	11.48	0.0641	0.0199	0.0442	5.64	2.93	2.25	0.37

---

[1] Loc. cit.

[2] Staz. sper. agr. ital. 1908, **41**, 433.

Respiration.—Gore,[1] working with 3 samples of Valencia oranges noted a maximum evolution of 23 mg. of carbon dioxide per kilo per hour at 29.3° C. and a minimum of 2 mg. at 1.7° C.

Effects of Freezing on Composition.—In experiments, conducted by Young[2] after the freeze of January 1913 in Southern California, part of the frozen and unfrozen fruit was kept in storage and part (" picks ") was left on the tree, analyses being made in both cases at intervals. The amount of juice extracted showed a large loss of water from the frozen fruit and analyses showed relatively greater losses of sugars and acid, causing a decrease in specific gravity of both fruit and juice. Average analyses of the juice appear in the following table:

	Sp. gr.	Citric acid	Sugars, total	Invert sugar	Sucrose
		%	%	%	%
Stored:					
Unfrozen......	1.052	1.49	9.06	4.62	4.44
Frozen........	1.046	1.35	7.42	3.60	3.82
Picks:					
Unfrozen......	1.051	1.45	9.03	4.12	4.90
Frozen........	1.045	1.38	7.44	3.67	3.79

Milliken, Tylor, Bonns, and Webber[3] state that the specific gravity of good fruit increases during storage while that of frozen fruit decreases. Small white spots consisting of hesperidin crystals appear in the pulp 5 to 10 days after freezing. In the same bulletin Thomas, Young, and Smith note that the specific gravity of the juice of frozen fruit was lower than that of unfrozen and that the total sugars of size 150, containing about 6.5 grams, decreased about 2.0 grams without change of the relative amounts of invert sugar and sucrose. The acid of frozen fruit suffered a progressive loss until practically none remained.

Nitrogenous Constituents.—As shown in a foregoing table, the nitrogen in the precipitate formed by lead subacetate and tannin decreases while the nitrogen in the filtrate remains practically constant.

Proteins of Seed.—Saunders[4] extracted from orange seeds, by solutions of various alkali halides, crystalline globulin preparations containing 16.8 to 17.1 per cent of nitrogen which are believed to be the same protein. Carpenter and Lovelace[5] measured the electrophoretic

[1] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[2] J. Ind. Eng. Chem. 1915, **7**, 1038.

[3] California Agr. Exp. Sta. 1919, Bul. **304**, 245.

[4] J. Am. Chem. Soc. 1931, **53**, 696.

[5] Ibid. 1933, **55**, 3738.

velocity of orange seed globulin in citrate and phosphate buffer solutions in the pH range of 1.5 to 7.8 and calculated the electric charge on the particles. The isoelectric point is given as pH 5.23 or C_H 5.9 × 10^{-6}.

Volatile Oil.—Hood[1] made determinations in several varieties of Florida oranges after separation of the peel from the pulp and distillation of the former with steam. At maturity he found 0.15 to 0.53 per cent of volatile oil calculated to the fruit. At various periods up to one and one-half months prior to maturity he found somewhat smaller amounts. Wilson and Young,[2] in the determination of volatile oil by the steam distillation method, measuring the oil of the distillate in the graduated neck of a special bottle, found that higher results were obtained when the whole fruit was used than when the pulp was separated from the peel and rejected. In Valencia oranges they report 0.70 to 1.29 per cent of volatile oil.

Chemical and Physical Values of the oil are given in Volume III.

Fatty Oil of Seed.—*Physical and Chemical Values* by Meyer,[3] Diedrichs,[4] Serger,[5] and Kobayashi[6] appear in the table below:

VALUES OF ORANGE SEED OIL

	Sp. gr. 15° C.	Ref. index 25° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Hehner No.	Fatty acids, titer	Acids as oleic
								° C.	%
Meyer....	0.923	......	229.0	104.0	....	....	95.0	35.0	....
Diedrichs..	0.9251	1.4643	196.4	97.3	0.71	0.40	95.6	34.3	0.81
Serger.....	0.9263	......	197.0	87.5	....	....	....	....	....
Koboyashi:									
I.......	0.9200	1.4702	192.7	105.3*	....	....	....	....	0.90
II......	0.9223	1.4712	193.4	113.0*	....	....	....	....	1.05
III.....	0.9221	1.4702	195.1	100.4*	....	....	....	....	4.97

* Wijs.

Acids.—Scurti[7] states that the acidity is due to *citric* and *malic acids* and that it diminishes up to a certain point during ripening. A number of other authors who have made special studies of the acids in fruits appear to have neglected the orange. Numerous figures on acidity appear in the foregoing tables.

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[1] J. Ind. Eng. Chem. 1916, **8**, 709.

[2] Ibid. 1917, **9**, 959.

[3] Chem. Ztg. 1903, **27**, 958.

[4] Z. Unters. Nahr.-Genussm. 1914, **27**, 132.

[5] Loc. cit.

[6] Loc. cit.

[7] Staz. sper. agr. ital. 1908, **41**, 456.

Carbohydrates.—Scurti and de Plato [1] found that both invert sugar and sucrose increase during ripening but in sour oranges the percentage of both is much less than in sweet oranges. Data on the amounts of reducing sugars and sucrose present in oranges of different varieties and at different stages of maturity appear in foregoing tables.

Bartholomew, Sinclair, and Raby [2] found that granulation of the juice in the vesicles causes a reduction in total sugars to 52 per cent and of reducing sugars to 67 per cent of that in healthy vesicles. Spraying the trees with lime water is recommended as a remedy.

Pectins.—See also Introduction, Apple, and Sugar Beet.

Harley [3] from dried albedo (white of peel) extracted over 11 per cent of crude pectin in the form of a white powder soluble in water, with the specific rotation +176.6°, and yielding galactan and arabinose on hydrolysis. From the fresh rind of the bitter orange Charpentier [4] extracted 10.5 per cent of pectins, with the specific rotation +170.5°, coagulating with pectase, and yielding on hydrolysis mucic acid, galactose, and arabinose. Ehrlich and Kosmahly [5] conclude that the pectic substance of orange peel consists of 2 acetyl, 1 arabinose, 1 galactose, 2 methyl, and 4 galacturonic acid groups and accordingly is diacetyl-arabino-galacto-dimethyl-tetragalacturonic acid, the formula being $C_{41}H_{60}O_{36}$. As in the case of the pectin of the sugar beet, by mild hydrolysis with 5 per cent hydrochloric acid the tetragalacturonic acid complexes may be split off.

Abbott [6] prepares pectin as a gray-white powder, from the peel of citrous fruits by extracting with hot alcohol, drying the residue *in vacuo* at 60° C., treatment with 0.4 to 0.5 per cent citric acid at 90° C. for one hour, and finally precipitating the pectin with alcohol.

From citrous albedo Myers and Baker [7] extracted by treatment at temperatures ranging from 40° C. to boiling, a series of pectins yielding acetic acid 2.19 to 5.3, methyl alcohol 7.83 to 12.75, and galacturonic acid 87.2 to 95.18 per cent. Only the galacturonic acid remains approximately constant at the higher temperatures of hydrolysis. They regard unhydrolyzed pectin as containing 2 acetyl, 1 arabinose, 1 galactose, 7 methyl, and 8 galacturonic groups with the formula $C_{70}H_{98}O_{58}$. Although the jellying power is dependent on the degree of polymerization of the galacturonic acid, neither the methoxyl content nor any other single constituent is a measure of jellying power.

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[1] Loc. cit.

[2] Calif. Citrograph 1934, **19**, 88, 106, 108.

[3] J. pharm. chim. 1912, **5**, 344.

[4] Bul. soc. chim. biol. 1924, **6**, 142.

[5] Biochem. Z. 1929, **212**, 162.

[6] Florida Agr. Exp. Sta. Rep. 1929, p. 60.

[7] Delaware Agr. Exp. Sta. 1932, Bul. **179**, 28; 1934, Bul. **187**.

Norris,[1] continuing the work of Schryver and co-workers (see Introduction), found that the pectic substance of orange juice is a trimethylated derivative of pectic acid similar to pectinogen extracted from the cell walls by oxalic acid or ammonium oxalate and is formed from the cell wall by the action of natural acids and enzymes. To prevent its conversion into an insoluble gel, the fruit is boiled before maceration.

Glucosides.—*Hesperidin,* a glucoside consisting of two molecules of hesperitin combined with two of glucose and one of rhamnose, is formed in the green fruit and persists to maturity, although in decreased percentages owing to the growth of the tissues. According to Power and Tutin [2] hesperitin is $C_6H_3(OCH_3)(OH)\cdot CH{:}CH\cdot CO\cdot C_6H_2(OH)_3$. The needle-shaped crystals of hesperidin melt at 251° C. They are only slightly soluble in water but soluble in alcohol and in ether. Their occurrence as white aggregates on the endocarp of frozen oranges has been noted above.

Hall [3] found in the endosperm of the mature navel orange, in addition to hesperidin, what appeared to be a soluble compound of glucose with hesperidin, also an accompanying similar substance related to hesperidin but with probably no glucose in its molecule.

Inosite.—Nelson and Keenan [4] report 0.0047 per cent of inosite in orange juice.

Matlack and Kremers [5] report briefly on the isolation from the peel of the sweet orange of *phytosterolin* which appears to be identical with the *phytosterol-d-glucoside* prepared by Salway in 1913 and the *ipuranol* of Power and Salway. It is accompanied by two phytosterols. They further identified palmitic, stearic, oleic, linolic, and linolenic acids.

Colors.—Zechmeister and Tuzson [6] state that the peel of the orange and the tangerine contains both a *water-soluble pigment* and a *carotenoid.* By alkaline hydrolysis of the colored wax, they obtained a crystalline substance, giving a blue color with dilute acid, that appeared to be identical with the *viola-xanthine* which Kuhn and Winterstein [7] found in *Viola tricolor.*

---

[1] Biochem. J. 1926, **20**, 993.

[2] J. Chem. Soc. 1907, **91**, 887.

[3] J. Am. Chem. Soc. 1925, **47**, 1191.

[4] Science 1933, **77**, 561.

[5] Am. J. Pharm. 1928, **100**, 599.

[6] Naturwissenschaften 1931, **19**, 307.

[7] Ber. 1931, **64B**, 326.

As isolated by Yamamoto and Tin,[1] employing Kuhn's method, 1 kg. of the fresh fruit of *Citrus poonensis* Hort. yielded carotene 33.1, caricaxanthine 170.3, free lutein 3.2, lutein ester 22.0, and viola-xanthine ester 48.2 mg. on the dry basis.

Odorous Constituents.—Hall and Wilson[2] isolated the following volatile constituents from Valencia orange juice: *ethyl alcohol, acetone, acetaldehyde, formic acid* (the foregoing soluble in water), *olefin alcohol* ($C_{10}H_{18}O$) forming 90 per cent of the constituents insoluble in water, *iso-* (?) *amyl alcohol, phenylethyl alcohol,* and *esters of formic, acetic,* and *caprylic acids. Geraniol* and *terpineol* also appeared to be present.

Mineral Constituents.—There is a paucity of literature on the ash of the edible portion of the orange, hence the value of the results on the pulp by Chace[3] given in the following table:

COMPOSITION OF ASH OF PULP OF CUBAN ORANGES (CHACE)

	Ash	K_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
China..........	0.52	40.66	10.26	5.27	1.09	8.56	2.84	1.01	2.44
Rough skin.....	0.55	49.19	2.62	1.41	4.51	7.42	3.42	....	1.50
Sour...........	0.57	45.09	7.95	2.17	2.40	8.70	2.72	....	0.98

Colby and Dyer[4] found 0.40 to 0.59, aver. **0.49** per cent of ash in 9 analyses of California oranges such as Navels, Mediterranean sweet, St. Michaels, and Blood, also 0.46 per cent in tangerines, and Pickel and Earle[5] found 0.69 to 1.24, aver. **1.00** per cent of ash in 10 varieties of Florida oranges, including Navels, Jaffa, Blood, Indian River, Bitter Sweet, Sour, and other varieties, also 0.67 per cent in tangerines and 0.50 per cent in mandarins. The minimum, maximum, and average results of ash analyses expressed in percentages of the ash are here tabulated. Although the total ash in the Florida oranges was about twice that in the California, no radical difference in the composition of the ash of the fruit from the two states was brought out by the analyses. The high percentage in the former case might be explained as due to low water content were it not that the results of water determinations show no such abnormality.

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[1] J. Agr. Chem. Soc. Japan 1933, 9, 642.

[2] J. Am. Chem. Soc. 1925, 47, 2575.

[3] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87, 29.

[4] California Agr. Exp. Sta. Rep. 1891/2, p. 99.

[5] Florida Agr. Exp. Sta. 1892, Bul. 17.

COMPOSITION OF ASH OF CALIFORNIA AND FLORIDA ORANGES

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
California										
Orange:										
Min.	40.3	1.4	16.4	4.3	0.2*	0.2	9.8	3.9	0.3	0.6
Max.	55.3	5.5	27.8	6.4	2.0*	0.6	14.7	7.9	1.5	1.4
Aver.	**48.1**	**2.9**	**22.6**	**5.4**	**0.9***	**0.4**	**12.9**	**5.1**	**0.8**	**0.9**
King orange	35.1	2.7	37.5	5.3	0.4*	0.4	10.6	6.1	1.2	0.5
Tangerine. .	47.9	1.7	26.6	5.5	0.9*	0.5	9.7	5.4	0.6	1.2
Florida										
Orange:										
Min.	39.1	2.7	16.1	3.5	0.2	. . .	7.7	3.2	0.1	0.6
Max.	56.8	5.0	32.6	6.3	1.0	. . .	9.4	5.6	2.1	1.8
Aver.	**50.2**	**4.0**	**23.9**	**4.8**	**0.6**	. . .	**8.5**	**4.4**	**1.1**	**1.1**
Tangerine. .	56.9	5.6	14.4	6.3	1.5	. . .	7.7	6.9	1.2	1.7
Mandarin. . .	57.9	4.6	12.9	4.2	0.8	. . .	9.6	5.2	1.6	1.6

* Includes alumina.

Additional analyses by Colby [1] of oranges, grown without fertilizer and with different chemicals, show an increase in ash in the fruit from fertilized trees, also certain differences in composition which, if attributable to the fertilizer, seem remarkable. For example, the highest lime content and the lowest phosphoric acid content were in fruit from trees fertilized with superphosphate of lime, and the highest potash content was in fruit from trees fertilized not with potash salt but with nitrate of soda.

Minor Mineral Constituents. *Iron.*—Edible portion 2 mg. per kilo, fresh basis (Bunge quoted by Sherman).[2] Peel 4.2, pulp 6.6, juice 2.8 mg. per kilo, fresh basis (Peterson and Elvehjem).[3] Whole fruit, 2 samples, 2.6, 6.0, juice, 2 samples, 2.0 3.6 mg. per kilo, fresh basis (Toscani and Reznikoff).[4]

Aluminum.—Edible portion 0.88 mg. per kilo, fresh basis (Underhill, Peterman, Gross, and Krause).[5] Peel 4.3, sections 5.6 mg. per kilo, dry basis (Bertrand and Lévy).[6]

Manganese.—Juice 1.41, peel 3.20 mg. per kilo, dry basis (McHargue).[7]

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[1] California Agr. Exp. Sta. Rep. 1894/5, p. 172.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. 185.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Nutrition 1934, **7**, 79.

[5] Am. J. Physiol. 1929, **90**, 72.

[6] Bul. soc. hyg. aliment. 1931, **19**, 359.

[7] J. Agr. Res. 1924, **27**, 417.

Copper.—Fruit 3.1 fresh basis, 21.9 mg. per kilo, dry basis (Guérithault).[1] Edible portion 0.8 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[2]

Zinc.—Seedless orange: peel 5.4, sections 1.7 mg. per kilo, fresh basis (Bertrand and Benzon).[3]

Arsenic.—Fruit 0.11 mg. per kilo, fresh basis (Jadin and Astruc).[4]

Boron.—Dunn and Bloxam,[5] in 7 samples of oranges, found boron in amounts equivalent to 3.5 to 14.2 mg. per kilo in the pulp and 26 to 58 mg. per kilo in the peel. They consider these amounts normal and not due to added preservative. They are, however, much higher than found by Scofield and Wilcox,[6] who report the following range in 4 samples of fresh California oranges irrigated with water containing 0.2 to 2.45 mg. per kilo of boron: pulp 1.3 to 4.1, peel 5.0 to 9.0 mg. per kilo.

BITTER ORANGE

Citrus Aurantium L. = *C. Aurantium* var. *amara* L. =
C. Aurantium var. *Bigaradia* Hook. f. = *C. vulgaris* Risso.

Fr. Bigarde. Sp. Naranjo agrio. It. Arancio amaro. Ger. Pomeranze.

Other names for this fruit are the sour or Seville orange. It appears to have originated in India.

The fruit is shipped to England in large quantities from Seville for the manufacture of marmalade and is preferred for that purpose to the common orange. The immature fruit is used in medicine. In the United States the chief value of the tree is as a stock on which to graft other citrous fruits.

MACROSCOPIC STRUCTURE.—This is similar to that of the common orange, but the flowers are larger, the mesocarp adhering to the segments is bitter, and the juice is high in acidity.

MICROSCOPIC STRUCTURE.—Tschirch and Oesterle's description corresponds closely with that of the common orange as given in the preceding section.

CHIEF STRUCTURAL CHARACTERS.—Rind more bitter and pulp more acid than in common orange, otherwise similar.

CHEMICAL COMPOSITION.—See Orange.

KING ORANGE

Citrus nobilis Lour.

The oblate-spheroidal *fruit* of this species from Cochin-China has a loose rough rind, free from the segments, and a hollow pith. The

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[1] Compt. rend. 1920, **171**, 196.

[2] J. Biol. Chem. 1929, **82**, 465.

[3] Bul. soc. hyg. aliment. 1928, **16**, 457.

[4] Compt. rend. 1912, **155**, 291.

[5] Analyst 1929, **54**, 28.

[6] Science 1930, **71**, 542.

eeds are more numerous than in the common orange, and the inner spermoderm, as well as the cotyledons, are often green, owing to the resence of chlorophyl grains. In other details of macroscopic and nicroscopic structure the fruit and seed agree closely with those of the common orange.

CHEMICAL COMPOSITION.—Analyses by Colby [1] of king oranges grown in California, also of its varieties, namely mandarin, satsuma, and tangerine, by Colby and by Wells, Agcaoili, and Orosa,[2] are given in the following table:

COMPOSITION OF KING ORANGE, MANDARIN, SATSUMA, AND TANGERINE

	Fruit							Juice				
	Weight	Peel	Seed	Marc	Water	Protein	Ash	Vol.	Solids	Citric acid	Sugars, total	Sucrose
	g.	%	%	%	%	%	%	cc.	%	%	%	%
King:												
Min.	104	23	1	18	82.00	1.40	0.71	25	14.35	1.25	11.60	5.44
Max.	165	49	3	32	82.00	1.40	0.71	90	15.35	2.20	14.62	6.13
Mandarin:												
Colby.	59	25	1	20	. . . . .	. . . .	. . . .	29	14.25	0.36	13.84	9.67
W. A. and O.	101	29	3	34	. . . . .	. . . .	. . . .	34*	9.02	0.51	7.59	4.85
Satsuma:												
W. A. and O.	386	30	1	26	. . . . .	. . . .	. . . .	43*	9.16	3.06	3.70	0.00
Tangerine:												
Colby.	55	26	2	31	84.90	0.97	0.46	22	13.80	0.87	11.03	7.41

* Per cent.

The composition of important members of the group, as determined by Hume,[3] appears in the following table:

	Weight	Peel	Seed	Flesh	Acids in juice	Sugars, total	K_2O	P_2O_5	N
	g.	%	%	%	%	%	%	%	%
Satsuma. . .	122	23.8	0.0	76.2	1.02	7.80	0.212	0.039	0.166
China.	140	21.4	3.6	75.0	0.84	7.49	0.258	0.076	0.140
Dancy	104	18.6	2.0	79.4	0.88	9.51	0.190	0.059	0.150
Oneco.	180	24.6	2.0	73.4	0.81	9.48	0.273	0.057	0.165
Cleopatra. .	60	37.3	4.3	58.4	1.56	7.20	0.320	0.053	0.164
King.	228	40.1	2.3	57.6	1.56	8.95	0.279	0.053	0.151

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[1] California Agr. Exp. Sta. Rep. 1891/2, p. 99.

[2] Philippine J. Sci. 1925, **28**, 45.

[3] Florida Agr. Exp. Sta. 1903, Bul. **66**, 571.

Nishioka and Matsumoto[1] determined protein, sugars, pectin, cellulose, acids, and ash during growth and storage of Satsuma oranges.

Mineral Constituents.—See Orange.

MANDARIN ORANGE AND TANGERINE

Citrus nobilis Lour. var. *deliciosa* Swingle

These two varieties are believed to have been derived by selection from the king orange from which they differ in having smaller, smoother, and redder fruit. The mandarin orange is from China, the tangerine from India. Both have flattened fruit with a very loose skin and rather small seeds with green cotyledons and occasionally a green inner spermoderm. The color is deep orange-red. Their peculiar spicy flavor is characteristic.

Their microscopic structure is like that of the common orange, except that chlorophyl grains occur in the inner spermoderm and cotyledons.

CHEMICAL COMPOSITION.—See also Orange and King Orange.

Separate analyses of the parts of Sicilian mandarin by Oliveri and Guerrieri[2] are tabulated herewith:

COMPOSITION OF PARTS OF MADARIN (OLIVERI AND GUERRIERI)

	Water	Protein	Fat	N-f. ext.	Acids	Sugars	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Peel (35%)..	72.50	1.50	3.85*	21.54†	....	....	....	....	0.61
Juice (50%) .	90.50	0.35	....	8.78	0.28‡	1.14	....	....	0.37
Marc (13%).	80.85	1.31	1.01	13.23	....	....	0.50	3.13	0.47
Seed (2%)..	60.62	12.31	1.05	25.18†	....	....	....	....	0.84

* Volatile oil. † Includes fiber. ‡ As citric.

Volatile Oil.—See Volume III.

Colors.—See also Orange.

Zechmeister and Tuzson[3] isolated *β-carotene* from both the fruit flesh and the rind of the mandarin orange. From the peel Nelson[4] isolated colorless rods and needles of *tangeretin*, $C_{15}H_5O_2(OCH_3)_5$, a pentamethyl flavonol isomeric with pentamethylquercetin, yielding on

[1] J. Chem. Soc. Japan 1931, **52**, 856, 865.

[2] Staz. sper. agr. ital. 1895, **28**, 287.

[3] Z. physiol. Chem. 1933, **221**, 278.

[4] J. Am. Chem. Soc. 1934, **56**, 1392.

alkaline hydrolysis anisic acid and tangeretol, a tetramethyl ketophenol isomeric with gossypitol tetramethyl ether.

A substance, soluble in benzol, and slightly in ether, but nearly insoluble in alcohol, was separated from the peel of the mandarin orange by Kimura and Nakamura.[1] Under certain conditions it showed intense fluorescence.

Mineral Constituents.—See Orange.

Minor Mineral Constituents. *Iron.*—Tangerine pulp 6.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Aluminum.—Mandarin peel 2.0, sections 6.6 mg. per kilo, dry basis (Bertrand and Lévy).[3]

Copper.—Tangerine pulp 0.9 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

Zinc.—Seedless mandarin peel 3.9, sections 0.8 mg. per kilo, fresh basis (Bertrand and Benzon).[5]

LEMON

Citrus Limonia Osbeck = *C. Medica* var. *Limon* L.
=*C. Limonium* Risso.

Fr. Citron. Sp. Limón. It. Limone. Ger. Limone.

Linnæus and the earlier botanists regarded the lemon and the lime as cultivated varieties of the citron, but later authors, including Swingle, separate them into as many species. The lemon originated in India and followed the citron into the Mediterranean region about the time of the Crusades.

Sicily is today a leading center of production and export, not only of the fresh fruit but also of lemon oil and citric acid. California leads in production in the United States; Florida, since the severe cold of 1894, has gone backward.

MACROSCOPIC STRUCTURE.—Lemon *flowers* are pink in the bud owing to the color of the lower side of the petals; otherwise they are much like those of the orange. The well-known characters of the *fruit* are the lemon yellow color, the elongated form and nipple end, the close union of rind and segments, the eight to ten segments, and the intense acidity. As in the orange, the surface has numerous short elevations over the oil cavities which become depressions on drying. The *seeds*, when present, are rather small and often polyembryonic.

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[1] Japan. J. Physics 1922, **1**, 41.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] Bul. soc. hyg. aliment. 1931, **19**, 359.

[4] J. Biol. Chem. 1929, **82**, 465.

[5] Bul. soc. hyg. aliment. 1928, **16**, 457.

MICROSCOPIC STRUCTURE. Pericarp.—The *chromatophores* of rind and vesicles are yellow. Another distinction from the orange is the occurrence of *sclerenchyma cells*, among the thin-walled cells of the epiderm of the vesicles, which stand out strongly on adding sodium hydroxide or safranin. In other microscopic characters, the pericarp closely resembles that of the orange.

Spermoderm.—The *outer epiderm* (Fig. 243, II) differs from that of the orange in that (1) the cells (seen in cross section) are not so high, (2) the double radial walls (also seen in cross section) are commonly broader than the lumen, and (3) the beaks (seen in surface view) are shorter, uniform in length, and occur along the whole length of the cell.

CHIEF STRUCTURAL CHARACTERS.—Fruit elongated with nipple; epicarp rough with small elevations over oil cavities as in orange; epicarp, hypoderm, and vesicles yellow; segments up to ten, closely adherent to rind. Seeds, if present, often polyembryonic.

Pericarp as in orange except that some of the epidermal cells of the vesicles are sclerenchymatous. Outer epidermal cells of spermoderm with walls broader than lumen and uniform beaks along whole length; other seed tissues as in orange.

CHEMICAL COMPOSITION.—Colby and Dyer and Colby included lemons in their study of California citrous fruits (see Orange). Water, protein, and ash were determined in only 11 and sucrose in only 4 of the 35 samples examined. Analyses by Danesi and Boschi[1] of 7 samples of Sicilian lemons and one by Wells, Agcaoili, and Orosa[2] are also included in the following table:

COMPOSITION OF CALIFORNIA, SICILIAN, AND PHILIPPINE LEMONS

	Fruit							Juice				
	Weight	Peel	Seed	Marc	Water	Protein	Ash	Vol.	Solids	Citric acid	Sugars, total	Sucrose
	g.	%	%	%	%	%	%	cc.	%	%	%	%
California:												
Eureka												
Min...	87	25	0	13	77.93	0.76	0.42	27	10.00	6.86	1.20	0.56
Max..	125	44	1	35	88.54	1.13	0.78	53	12.95	8.33	3.60	0.58
Lisbon												
Min...	103	19	0	20	87.00	0.87	0.44	40	10.20	7.00	1.35	....
Max..	117	38	2	25	87.20	1.04	0.51	50	11.50	7.84	3.10	....
All var.:												
Min...	80	13	0	13	77.93	0.69	0.42	23	9.08	5.74	1.20	0.35
Max..	170	50	3	38	88.54	1.14	0.78	95	13.20	8.40	3.60	0.58
Sicilian:								%				
Min.....	115	35*	1	16	78.12†	....	....	34	9.90	6.51	0.07‡	....
Max....	128	44*	3	23	83.65†	....	....	44	13.38	7.21	0.96‡	....
Philippine	58	34	1	40	.....	....	....	26	7.39	3.71	0.97‡	0.00

* Volatile oil in peel 1.04 to 1.57%. † In fruit flesh. ‡ Reducing sugars.

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[1] Staz. sper. agr. ital. 1895, **28**, 699.

[2] Philippine J. Sci. 1925, **28**, 453.

Two analyses by Chace, Tolman, and Munson[1] of the edible part of Cuban sweet lemons and one by Thompson,[2] by practically the same methods, of the unfiltered juice of Hawaiian rough lemons, obtained by squeezing without removal of the peel, are tabulated below:

COMPOSITION OF CUBAN AND HAWAIIAN LEMONS

	Edible part in fruit	Water	Solids, insol.	Protein	Fat	Citric acid	Sugars, total	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	%
Cuban:											
Sweet (E. P.).	..	88.77	2.43	....	....	0.17	7.21	1.22	....	0.62	0.54
Sweet (E. P.).	71	89.63	....	....	....	0.09	5.27	0.99	....	0.98	0.41
Hawaiian:											
Juice........	33	93.56	0.30	0.36	1.49	4.41	2.00	0.47	0.08	0.23	....

* As potassium carbonate.

Composition of Basal and Apical Ends.—Bartholomew[3] failed to detect any difference in the acidity of the two halves. After the fruit reached a diameter of 3 to 4 cm., the acidity of the whole fruit changed very little, although the total acid (free and combined) increased rapidly toward the end of the growing period.

Composition of Parts.—Separate analyses of the parts of Sicilian lemons by Oliveri and Guerrieri[4] are tabulated below:

COMPOSITION OF PARTS OF LEMON (OLIVERI AND GUERRIERI)

	Water	Protein	Fat	N-f. ext.	Citric acid	Sugars	Starch	Fiber	Ash
	%	%	%	%	%	%	%	%	%
Skin (42%).	76.38	1.79	1.01*	20.30†	....	....	....	....	0.52
Juice (42%).	90.79	0.32	....	8.69	5.86	0.87	....	....	0.20
Marc (14%).	82.91	1.44	0.81	11.47	....	....	0.20	2.97	0.40
Seed (2%)..	44.74	14.00	0.95	39.40†	....	....	....	....	0.91

* Volatile oil. † Includes fiber.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[3] Am. J. Bot. 1923, **10**, 117.

[4] Staz. sper. agr. ital. 1895, **28**, 287.

Results by Ajon[1] on pulp and juice, in the latter case in terms of grams per 100 cc., appear below:

	Solids	Protein	Acids, free	Acids, combined	Sugars	Pectin, total	Pectin, soluble	Protopectin	Pentosans	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
Pulp...	14.68	0.68	6.47	0.43	1.06	0.94	0.33	0.59	0.69	0.55	0.47*
Juice...	11.34	0.31	8.14	0.38	1.05	....	0.07	....	....	....	0.36†

* Alkali 0.41%. † Alkali 0.35%.

Composition of Lemon Juice.—Analyses of freshly prepared lemon juice have been made by Huerre[2] and Azadian,[3] 3 samples each, for comparison with commercial lemon and lime juices. The samples designated, Adalia, Beledi, and Sweet were from the common Italian variety, the West Indian variety, and *C. bergamia* respectively, all grown in Egypt.

COMPOSITION OF LEMON JUICE

	Sp. gr.	Solids	Citric acid	Malic acid	Sugars, total	Sucrose	Pectin	Ash
		%	%	%	%	%	%	%
Huerre:								
Min........	1.048	11.73*	7.00	0.4	2.2	0.4	0.4†	1.6
Max........	1.064	11.73*	7.50	0.6	2.5	0.5	0.4†	1.8
Azadian:								
Adalia......	1.036	7.84	6.40‡	...	...	...	0.29	0.35
Beledi.......	1.040	9.71	7.70‡	...	...	...	0.32	0.31
Sweet.......	1.038	9.20	0.04‡	...	3.6	...	0.39	0.29

* Grams per 100 cc. † Includes mucilage. ‡ Acid as citric.

Fermented Lemon Juice.—In lemon juice containing about 8.59 per cent of alcohol and 4.20 per cent of free citric acid, Wolfrum and Pinnow[4] isolated 1.29 per cent of the ethel ester of citric acid, also 0.04 per cent of acetic acid, 0.023 per cent of succinic acid, and 0.07 per cent of glycerin.

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[1] Riv. ital. essenze profumi 1929, **11**, 107.

[2] J. pharm. chim. 1919, **20**, 5.

[3] Ann. fals. 1925, **18**, 412.

[4] Z. Unters. Nahr.-Genussm. 1915, **30**, 144.

Influence of Time of Ripening on Composition.—Chace, Wilson, and Church[1] determined specific gravity, essential oil, and acid in ripe lemons of 3 varieties from different sections of California at monthly intervals. They report the individual analyses, the average for each tree, and the average for each variety. In the following summary the lowest and highest figures of the individual analyses and the general averages are given:

Composition of California Lemons Ripened at Different Seasons (Chace et al.)

	Sp. gr.	Oil in fruit	Acids* in fruit	Acids* in juice
		%	%	%
Eureka:				
Min.	0.8912 Jan.	0.30 Jan.	1.91 Nov.	5.39 Apr.
Max.	0.9853 Nov.	0.67 Nov.†	4.41 Oct.	7.74 Sept.
Aver.	**0.9383**	**0.48**	**3.22**	**6.61**
Lisbon:				
Min.	0.8375 July	0.30 Mar.	2.57 Oct.	5.81 Apr.
Max.	0.9666 Dec.	0.84 Dec.	4.05 Oct.	8.05 Dec.
Aver.	**0.9168**	**0.50**	**3.23**	**6.78**
Villa Franca:				
Min.	0.8753 Mar.	0.38 Apr.	2.19 Dec.	5.42 Aug.
Max.	0.9631 Aug.	0.74 Aug.	4.16 Sept.	7.58 Nov.
Aver.	**0.9262**	**0.53**	**3.13**	**6.60**

* As citric acid plus water of crystallization. † Also June.

The extreme results of individual analyses are of interest as showing the range in composition but in some cases are at variance with the authors' conclusions based on a consideration of all the results as follows: (1) specific gravity is highest in midsummer and lowest in Winter, (2) the oil content is highest in Fall and lowest in late Winter and Spring, and (3) the acidity is highest in early Fall.

Effects of Freezing on Composition.—Experiments by Young gave results comparable with his results on oranges (which see) except that the percentage of sucrose appears to increase on freezing, thus offsetting to some extent the considerable loss of invert sugar.

Respiration.—Gore,[2] working with 3 samples each of partly green and fairly well yellowed Eureka lemons, noted a maximum evolution of 20 mg. of carbon dioxide per kilo per hour at 29.3° C. and a minimum of 2 mg. at 1.7° C.

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[1] U. S. Dept. Agr. 1921, Bul. **993**.

[2] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

Nitrogenous Constituents.—Scurti and de Plato[1] found that the total asparagine and glutamine, present in the earlier periods of ripening, are used up in the formation of proteins.

Volatile Oil.—See Volume III.

Fatty Oil of Seed.—Oliveri and Guerrieri[2] found only 0.95 per cent of fat in the seeds. So low a percentage indicates abortion. Diedrichs[3] reports 50 per cent as the approximate amount. Values of the oil by Peters and Frerichs,[4] Diedrichs,[3] Bertolo,[5] and Bennett,[6] who found little difference between hot and cold pressed oils, are tabulated below:

VALUES OF LEMON SEED OIL

	Sp. gr. 15° C.	Ref. index 25° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Hehner No.	Acetyl No.	Fatty acids, titer	Acid No.
									°C.	
P. and F...	0.900	......	188.4	109.2	....	....	....	13.7	....	3.1
Diedrichs...	0.925	1.4712	196.0	107.3	0.55	0.30	95.6	....	....	0.9*
Bertolo:										
Expressed	0.922	1.4723	190.0	103.0	....	....	94.0	....	35	2.82*
Extracted	0.924	......	191.0	108.0	....	....	....	....	....	....
Bennett....	0.923	......	189.0	109.0	....	....	....	....	31.9	11.6*

* Per cent of acid as oleic.

Acids.—Ricevuto,[7] from the results of analyses of lemons from the same tree, made every fifteen days, concludes that *citric acid* is formed during the warm months from reducing sugars and pentosans, but during the colder months only from pentosans.

Carbohydrates.—According to Fichera,[8] the "outer membrane" consists of cellulose and other polysaccharides, galactosan, and glucosan, the "inner (vesicular) membrane" of cellulose and glucosan. The outer membrane yields, with nitric acid, mucic acid (from galactan) and on hydrolysis with sulphuric acid yields galactose, dextrose, and traces of rhamnose. About 40 per cent of the dry weight consists of cellulose. The inner membrane yields dextrose on acid hydrolysis.

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[1] Staz. sper. agr. ital. 1908, **41**, 456.

[2] Ibid. 1895, **28**, 287.

[3] Z. Unters. Nahr.-Genussm. 1914, **27**, 132.

[4] Arch. Pharm. 1902, **246**, 659.

[5] Giorn. chim. appl. 1920, **1**, 54.

[6] Perf. Ess. Oil Rec. 1922, **13**, 260.

[7] Ann. chim. appl. 1933, **23**, 411.

[8] Ibid. 1925, **15**, 568.

Inosite.—Nelson and Keenan[1] report 0.0124 per cent of inosite in lemon juice.

Pectins.—Sucharipa[2] classifies the pectin substances of the lemon as: (1) *free* or *soluble pectin*, the fully methylated ester of pectic acid, occurring in the juice and the outer layer of the wall of the individual cell (middle lamella of the double wall), which appears to correspond to the pectin of Von Fellenberg; (2) *protopectin*, so named by Tschirch, an insoluble constituent of the cell layer adjoining the outer layer, which was shown by Von Fellenberg to be the methyl ester of pectic acid and not the calcium salt as thought by earlier workers; and (3) *pectic acid*, practically insoluble in water, the ultimate product of hydrolysis of any of the pectic substances. He refers to the confusion of terms used by different authors and he himself uses pectin and pectic acid interchangeably. (See also Introduction, Apple, Orange, and Beet.)

In lemon albedo (white of peel) Sucharipa found: ash 3.32, matter soluble in ether and alcohol 12.54, total pectin, including " free " and hydrolyzed 21.64, total of substances extracted with pectin 29.43, free cellulose 15.00, total hydrolyzed cellulose 8.94, and unaccounted for 9.13 per cent.

Myers and Baker[3] studied the yield of pectin from lemon albedo as influenced by hydrogen-ion concentration, temperature, and time of extraction. Increase of *p*H beyond the optimum decreased the yield, time and temperature remaining constant, but increase in temperature decreased the *p*H essential for the maximum yield. When the *p*H was below 3.0 there was practically no yield of pectin at 60° C. or less in 30 minutes but when the *p*H was increased sufficiently there was a marked formation, even at room temperature.

The constituent units of the pectin contained in lemon albedo, identified by Bridgham and King,[4] are *d*-galacturonic acid, *l*-arabinose, *d*-galactose, and methyl alcohol, the molecular proportion of the first three being 4:1:1. The galacturonic acid units are present in the native pectin chiefly as methyl esters.

Colors.—Denny[5] states that lemons which are green when sufficiently mature for picking become yellow on storage for 30 to 60 days at 10 to 13° C. in air with a humidity of 80 per cent. This change may be hastened by exposing the fruit to the gases liberated by kerosene stoves or to ethylene mixed with air, the rate of coloring being influenced by the concentration and the temperature. See also Lime.

[1] Science 1933, **77**, 561.

[2] J. Am. Chem. Soc. 1924, **46**, 145.

[3] Delaware Agr. Exp. Sta. 1931, Tech. Bul. **12**;

[4] J. Am. Chem. Soc. 1933, **55**, 3319.

[5] J. Agr. Res. 1924, **27**, 757.

Mineral Constituents.—The range of 4 analyses by Colby[1] of the ash of California lemons, all but one of the Eureka variety, one analysis by Ajon[2] of the ash of the pulp of Italian lemons, and one by Chace[3] of the ash of the pulp of Cuban sweet lemons are given in the following table:

COMPOSITION OF LEMON AND LEMON PULP ASH

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Lemon:										
California										
Min....	30.05	1.50	25.17	4.00	0.28*	0.28	10.19	2.48	0.54	0.27
Max...	51.20	4.39	36.07	6.12	1.36*	0.71	19.63	4.15	0.92	0.88
Pulp:										
Italian...	54.63	17.14	10.17	4.33	0.19	....	9.68	3.47	....	0.28
Cuban...	54.35	.....	4.29	1.08	....	....	9.83	4.09	....	1.32

* Includes Al_2O_3.

Minor Mineral Constituents. *Iron.*—Peel 7.5, juice 1.5 mg. per kilo, fresh basis (Peterson and Elvehjem).[4]

Manganese.—Peel 4.12, juice 3.38 mg. per kilo, dry basis (McHargue).[5] Peel 6.75 mg. per kilo, dry basis, pulp trace, seed trace (Quartaroli).[6] Fruit 3.6 mg. per kilo, dry basis (Peterson and Skinner).[7]

Copper.—Peel 3.12, pulp 2.04, seed 12.2 mg. per kilo, dry basis (Quartaroli).[6] Pulp 0.4 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[8]

Zinc.—Pressed peel and residue 3.3, juice 1.7 mg. per kilo, fresh basis (Bertrand and Benzon).[9]

LIME

Citrus aurantifolia Swingle = *C. limetta* Auct. =
Limonia aurantifolia Christ.

Fr. Lime. Sp. Lima. Ger. Lime.

The common lime grown in the West Indies and southern Florida is a small green-yellow fruit with a slight beak, a strongly acid pulp, and small seeds. It is used for "limeade" which is prepared either from the fresh fruit or the bottled juice. The larger-fruited lime is more insipid.

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[1] California Agr. Exp. Sta. Rep. 1891/2, p. 99.

[2] Loc. cit.

[3] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

[4] J. Biol. Chem. 1928, **78**, 215.

[5] J. Agr. Res. 1924, **27**, 417.

[6] Ann. chim. appl. 1928, **18**, 47.

[7] J. Nutrition 1931, **4**, 419.

[8] J. Biol. Chem. 1929, **82**, 465.

[9] Bul. soc. hyg. aliment. 1928, **16**, 457.

MICROSCOPIC STRUCTURE.—In structure the lime resembles the lemon. *Sclerenchyma cells* may occur in the epiderm of the vesicles, and the *outer epiderm* of the spermoderm has numerous beaks along the whole length of the cells, although these beaks may be longer at the ends of the cells, whereas in the lemon they are more nearly uniform.

Chief Structural Characters.—Fruit very small, oval; segments ten; seeds small. Histology nearly the same as that of lemon.

CHEMICAL COMPOSITION.—The composition of one sample of California limes as found by Colby[1] and of 3 samples of Philippine limes as found by Wells, Agcaoili, and Orosa[2] is shown in the following table:

Composition of California and Philippine Limes

	Fruit				Juice				
	Weight	Peel	Seed	Marc	Vol.	Solids	Citric acid	Sugars, total	Sucrose
	g.	%	%	%	cc.	%	%	%	%
California .	117	21	..	23	60	9.70	5.18	3.48	....
Philippine:					%				
Min. . . .	34	20	0	21	45	8.47	6.64	0.06	0.00
Max. . . .	120	30	1	34	48	9.81	7.16	1.69	0.00

Three samples of Cuban limes, analyzed by Chace, Tolman, and Munson,[3] and one of the juice of Hawaiian limes, analyzed by Thompson,[4] contained as given in the following table:

Composition of Cuban and Hawaiian Limes

	Weight	Edible part	Water	Solids, insol.	Protein	Fat	Citric acid	Sugars, total	Sucrose	Fiber	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	%	%	%
Cuban:												
I.	27	78	85.23	3.97	0.83	....	7.20	0.34	0.00	....	0.67	0.64
II	26	69	85.16	....	....	....	6.27	0.58	0.00	....	0.98	0.73
Hawaiian:												
Juice. . .	..	49	88.25	0.11	0.67	3.56	8.93	1.50	0.00	0.07	0.35	....

* As potassium carbonate.

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[1] California Agr. Exp. Sta. Rep. 1894/5, p. 172.

[2] Philippine J. Sci. 1925, **28**, 453.

[3] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[4] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

Analyses of lime seeds and lime seed cake, after removal of 30 per cent of oil,[1] appear below:

COMPOSITION OF LIME SEEDS AND CAKE

	Water	Protein	Protein, pure	Fat	Carbohydrates	Fiber	Ash	K_2O	P_2O_5
	%	%	%	%	%	%	%	%	%
Seed...	10.54	21.37	14.50	39.87	11.90	14.10	2.22	0.48	0.74
Cake...	15.08	30.50	20.70	14.20	17.00	20.05	3.17	0.88	1.05

Nitrogenous Constituents of Lime Juice.—Frank[2] isolated a substance ($C_6H_7O_2N_5$), readily soluble in hot water, that failed to give the usual purine reactions, also spherolites, melting with decomposition at 188 to 189° C., corresponding to methylpiperidylacetic betaine ($C_9H_{18}O_6N_2$).

Volatile Oil.—See Volume III.

Fatty Oil of Seeds.—Examination of the oil of lime seeds, made at the laboratories of the Imperial Institute and of the Leeward Islands,[3] gave the values tabulated below:

VALUES OF LIME SEED OIL

	Sp. gr. 15°/15°	Ref. index 25° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Fatty acids, titer	Acid No.	Unsapon. matter
							° C.		%
Imp. Inst..	0.9236	1.4689	197.7	109.5	0.27	0.48	34.9	13.6	0.4
L. Islands.	0.9212	1.4750	193.6	100.8	....	....	....	11.2	0.7

Pectins.—As determined by Adriano, Ylizarde, and Villanueva,[4] the rind of Tahiti limes contained 2.63 per cent of pectin, which is more than was present in any of 13 other Philippine fruits examined.

Colors.—Unlike the color of orange, mandarin, and tangerine peel, that of lime, lemon, and grapefruit peel, according to Hardy and Warneford,[5] is largely in the form of a *phlobatannin* (polyhydroxyphenolic compound) occurring in the vacuole contents of the cells bordering on the oil cavities. Very little carotenoid pigment or true anthroxanthine is present. On boiling the peels with acids a dark brown phlobatannin is formed. Fusion with potash results in the formation of protocatechuic acid, and hydrolysis with potash solution yields caffeic acid. This coloring matter is present in lime juice pressed from the whole fruit; in contact with the air it oxidizes, giving the product an unsightly brown or almost black coloration.

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[1] Bul. Imp. Inst. 1922, **20**, 465.

[2] Biochem. J. 1913, **7**, 81.

[3] Bul. Imp. Inst. 1922, **20**, 465.

[4] Philippine J. Agr. 1932, **3**, 273.

[5] Ind. Eng. Chem. 1925, **17**, 48.

Mineral Constituents.—Chace[1] found 0.98 per cent of ash in the pulp of limes from Cuba and the percentages of constituents in the ash tabulated below:

K_2O	CaO	MgO	P_2O_5	SO_3	Cl
%	%	%	%	%	%
43.01	7.84	2.36	8.45	2.62	4.07

CITRON

Citrus Medica L. = *C. Medica* var. *macrocarpa* Risso

Fr. Cédrat. Sp. Cidra. It. Cedrato. Ger. Zitrone.

Originally an Indian species, the citron was introduced into southern Europe before the lemon. It is valued for the fleshy rind which, candied, is the citron of commerce. It is grown chiefly in Italy, southern France, Corsica, Sicily, and other Mediterranean countries whence it is shipped in brine to be candied as needed.

The rind has the same histological elements as that of the orange and lemon. Endocarp, vesicles, and seeds are lacking in the candied rind.

As a substitute, the rind of the citron melon (*Citrullus vulgaris* Schrad.) is also candied.

CHEMICAL COMPOSITION.—Analyses of the candied peel as given by Atwater and Bryant[2] follow:

	Samples	Water	Protein	Fat	N-f. ext.*	Ash
		%	%	%	%	%
Min.......	2	12.4	0.4	0.6	72.5	0.8
Max.......	2	25.6	0.6	2.5	83.7	0.9
Aver.......	2	**19.0**	**0.5**	**1.5**	**78.1**	**0.9**

* Includes fiber.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87, 29.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

GRAPEFRUIT

Citrus grandis Osbeck = *C. Aurantium* var. *grandis* L. = *C. decumana* L.

Fr. Pompelmouse. It. Pomo di paradiso. Ger. Pompelmus.

The name grapefruit refers to the growth in bunches. Florida, which produces several times as much as all other regions together, Puerto Rico, and other West Indian Islands supply the Winter and Spring market, the varieties being mostly rich in seeds, while California supplies the Spring and Summer market with a limited amount of seedless fruit.

The pummelos are pear-shaped, thick rind varieties of the same species as the grapefruit, grown mostly in the Orient. Under the name of shaddock a variety of pummelo was formerly grown in Florida to some extent but now is of little importance. One variety of pummelo (Bombay Red) described by Swingle has very juicy pulp the color of raw beef.

MACROSCOPIC STRUCTURE.—Both buds and *flowers* are white. The *fruit* is lemon colored, globular, and remarkable for its large size. The segments vary up to 14. Some varieties have such bitter rind and endocarp that care must be taken in eating to exclude all but the vesicles. This objection is removed in newer varieties without loss of piquancy of flavor. The *seeds* are large and generally prominently beaked; many contain more than one embryo.

MICROSCOPIC STRUCTURE. Pericarp.—The structure is practically the same as that of the lemon, the epidermal cells of the vesicles being partly sclerenchymatized.

Spermoderm.—The outer epiderm (Fig. 243, III) is intermediate between that of orange seed and lemon seed. In height it resembles the former. The double radial walls in some parts are broader than the lumen, in other parts narrower. In surface view, the end beaks of the cells are prominent as in the orange but occasional short beaks between the end beaks are also present. The short beaks are neither so prominent nor so numerous as in the lemon.

CHIEF STRUCTURAL CHARACTERS.—Fruit globular, very large; epicarp smooth except over oil cavities; epicarp, hypoderm, and vesicles yellow; segments up to 14, closely adherent to rind. Seeds large, beaked, polyembryonic.

Pericarp tissues throughout as in lemon. Outer epidermal cells of spermoderm with occasional short beaks along cell between the two long end beaks, lumen often narrower than double radial wall.

CHEMICAL COMPOSITION.—Two analyses of California pomelos by Colby[1] and the minimum and maximum results of 9 analyses of Philippine grapefruit by Wells, Agcaoili, and Orosa[2] follow:

COMPOSITION OF CALIFORNIA POMELOS AND PHILIPPINE GRAPEFRUIT

	Fruit				Juice				
	Weight	Peel	Seed	Marc	Vol.	Solids	Citric acid	Sugars, total	Sucrose
	g.	%	%	%	cc.	%	%	%	%
California:									
Pomelo....	440	23	3	25	175	11.20	2.31	8.00	....
Pomelo....	357	24	4	37	...	13.20	2.70	9.50	5.00
Philippine:									
Grapefruit					%				
Min....	280	25	0	18	32	8.21	0.38	2.22*	2.11
Max....	695	39	4	36	48	10.96	1.76	3.57*	5.19
Aver....	**409**	**32**	**2**	**27**	**39**	**9.18**	**1.28**	**2.82***	**3.08**

* Reducing sugar.

The minimum and maximum results of 3 analyses of Cuban grapefruit by Chace, Tolman, and Munson[3] and single analyses of Philippine pomelo by Pratt and Del Rosario[4] and of Hawaiian shaddock by Thompson[5] are given below:

COMPOSITION OF EDIBLE PART OF CUBAN GRAPEFRUIT, PHILIPPINE POMELO, AND HAWAIIAN SHADDOCK

	Weight	Edible part in whole	Water	Solids, insol.	Protein	Fat	Citric acid	Sugars, total	Sucrose	Fiber	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	%	%	%
Grapefruit:												
Min......	378	69	86.71	1.17	0.56	....	0.71	5.89	3.11	....	0.39	0.31
Max.....	477	73	90.06	2.70	0.58	....	0.77	7.37	4.77	....	0.46	0.37
Pomelo......	930	61	87.70	2.60	0.66	....	1.06	9.15	6.24	....	0.63	0.44
Shaddock...	...	42	88.47	6.14	1.18	0.14	0.26	8.12	7.26	1.98	0.49	0.20

* As potassium carbonate.

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[1] California Agr. Exp. Sta. 1892/4, p. 253; 1894/5, p. 172.

[2] Philippine J. Sci. 1925, **28**, 453.

[3] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[4] Philippine J. Sci. 1913, **8**, 59.

[5] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

Baier[1] lays stress on the average solids : acid ratio in the Marsh variety which varied from 5.40:1 to 6.78:1, being highest in fruit from the most arid regions.

Composition of Seed.—Jamieson, Baughman, and Gertler[2] state that the air-dry seed contains 30 per cent or more of oil, and the extracted seed: protein 21.4, nitrogen-free extract 38.8, and fiber 22 per cent.

Changes in Composition during Storage.—This problem was attacked by Zoller,[3] who found that the content of citric acid, naringin, and pectin decreased and of reducing sugars and sucrose increased during storage, and later by Hawkins and Magness[4] and Hawkins.[5] Hawkins found that during warm storage for 2 months the acid content, calculated to the wet pulp, increased markedly and the total sugar content slightly, whereas during cold storage for 4 months at 0° C. there was a marked decrease in acidity but little change in the total sugar content. When left on the tree the acidity decreased and the total sugar content increased. The influence of cold storage is shown by the average results obtained with the fruit of 3 trees, picked Oct. 4, Nov. 1, and Dec. 9, the loss in acidity being evident even if no account is taken of the shrinkage which in the three cases amounted to 4.3, 3.9, and 4.2 per cent.

Average Composition of Florida Grapefruit before and after Storage 4 Months at 0° C.

	Peel	Peel thickness	Solids	Acids	Sugars, total	Sugars, reducing	Sucrose	Acid in juice	Solids in juice	Solids: acid
	%	mm.	%	%	%	%	%	%	%	ratio
3rd Pick:										
Before	23.2	5.4	9.24	1.09	5.26	2.55	2.71	1.30	9.13	7.03
After	24.6	4.8	9.23	0.98	5.29	2.52	2.77	1.18	10.41	8.83
4th Pick:										
Before	21.9	4.5	9.49	1.13	5.86	2.88	2.98	1.25	10.07	8.08
After	21.7	4.4	9.80	1.03	6.33	3.35	2.98	1.07	9.92	9.58
5th Pick:										
Before	20.5	3.8	9.98	1.20	6.79	3.64	3.15	1.25	10.65	8.52
After	22.4	4.7	9.96	1.11	6.36	3.33	3.03	1.13	11.04	9.75

The above results show a progressive increase in total sugar for the three picks before storage and a slight gain in acid. Considered, however, in connection with the first two picks (results not here given) there was a distinct loss in acid in the later picks.

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[1] Calif. Citrograph 1932, **17**, 94.

[2] Oil & Fat Ind. 1930, **7**, 181.

[3] J. Ind. Eng. Chem. 1918, **10**, 364.

[4] J. Agr. Res. 1920, **20**, 357.

[5] Ibid. 1921, **22**, 263.

Nitrogenous Bases.—Hiwatari[1] isolated from 27 kg. of the pulp: glycine-betaine 2.2, stachydrine 8.5, and putrescine 0.2 gram.

Volatile Oil.—See Volume III.

Fatty Oil of Seed.—The composition of the expressed oil, as found by Jamieson, Baughman, and Gertler,[2] follows:

	%
Glycerides of:	
Lignoceric acid	0.1
Stearic acid	7.6
Palmitic acid	20.1
Oleic acid	20.5
Linolic acid	51.0
Unsaponifiable matter	0.7
	100.0

Acids.—Menchikowsky and Popper[3] give the following average results on acids in whole Palestine grapefruit and the juice: *citric acid* 0.6700 and 1.5810, *tartaric acid* 0.0003 and 0.0007, *malic acid* 0.0069 and 0.0163, and *oxalic acid* 0.0022 and 0.0053 per cent respectively.

Glucoside.—Attention is called by Zoller[4] to the bitter principle of the peel, *naringin*, so named by Hoffmann,[5] which was discovered by De Vry.[6] Neither of the authors was able to find the glucoside in other citrous fruits or parts of their plants. Its empirical formula is given as $C_{21}H_{26}O_{11} \cdot 4H_2O$. On hydrolysis it yields rhamnose and dextrose, the latter in the smaller amount. Zoller prepared naringin from the residue after steam distillation of the peel and from a 96 per cent alcohol percolate as white, glistening, spine-like crystals.

Zoller found in fresh and old grapefruit the following amounts of naringin: Indian River 0.080 and 0.048, Walters 0.073 and 0.034, and Marsh Seedless 0.066 and 0.014 per cent, calculated to the whole fruit. Apparently the glucoside splits up with the liberation of its carbohydrate constituents. Fellers[7] also found that naringin decreases in amount with maturity. Analyses by Poore[8] of grapefruit residue from canning

[1] J. Biochem. Japan 1927, **7**, 169.

[2] Loc. cit.

[3] Hadar 1932, **5**, 181.

[4] J. Ind. Eng. Chem. 1918, **10**, 364.

[5] Ber. 1876, p. 685.

[6] Jahresb. Pharmacog. 1857, **132**, 1866.

[7] Glass Packer 1929, **2**, 509.

[8] Ind. Eng. Chem. 1934, **25**, 637.

plants show pectin 3 to 4.5 per cent and naringin 0.75 per cent, both of which substances may be largely recovered.

Inosite.—Nelson and Keenan [1] report 0.0028 per cent of inosite in grapefruit juice.

Colors.—See Lime.

Mineral Constituents.—Chace [2] found 0.39 per cent of ash in Cuban grapefruit and the following percentages of constituents in the ash:

K_2O	CaO	MgO	Fe_2O_3	P_2O_5	SO_3	Cl
%	%	%	%	%	%	%
44.19	7.34	3.92	1.28	11.09	3.39	1.38

Minor Mineral Constituents. *Iron.*—Pulp 2.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Copper.—Pulp 0.3 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).

KUMQUAT

Fortunella spp.

Of several cultivated species of the genus, introduced into the United States from China and Japan, the oval or nagami kumquat (*F. margarita* Swingle = *Citrus margarita* Lour.) now has reached the shipping stage. Swingle considers the Hongkong wild kumquat (*F. Hindsii* Swingle) the most primitive of true citrous fruits.

The diminutive fruits are eaten out of hand. They make excellent marmalade. Candied and preserved round kumquats (*F. japonica* Swingle = *Citrus japonica* Thunb.) are imported from China.

MACROSCOPIC STRUCTURE.—The small *flowers* resemble those of species of *Citrus* but the ovary usually has fewer cells (up to seven). Characteristic of the *seed* are the bright green cotyledons; the inner spermoderm, however, is brown as in the orange.

MICROSCOPIC STRUCTURE. Pericarp.—As in the orange.

Spermoderm.—The *outer epiderm* does not conform to any of the three forms found in the orange, lemon, or grapefruit. Beaks occur all along the outer wall as in the lemon but are longer, branching, and jagged.

Cotyledons.—Numerous chlorophyl grains cause the green coloration.

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[1] Science 1933, **77**, 561.

[2] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] Ibid. 1929, **82**, 465.

CHIEF STRUCTURAL CHARACTERS.—Fruit small, elongated or round, up to seven-loculed; inner spermoderm brown; cotyledons bright green.

Pericarp as in orange. Spermoderm with branching beaks along outer epidermal cells.

Chemical Composition.—No proximate analyses of whole fruit available. For an analysis of the seed see Composition of Parts under Orange.

Minor Mineral Constituents. *Iron.*—Fruit 5.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[1]

Copper.—Fruit 0.8 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[2]

MISCELLANEOUS CITROUS FRUITS

The following citrous fruits grown in the Philippines have been analyzed by Wells, Agcaoili, and Orosa[3]: Biasong (*Citrus micrantha* Wester), Ganid (*C. Webberi* var. *montana* Wester), Camisan (*C.* sp.), Lambog (*C. pseudolimonum* Wester), and Suangui (*C. hystrix* var. *torosa* Wester).

	Fruit					Juice			
	Weight	Peel	Seed	Marc	Juice	Solids	Citric acid	Sugars, total	Sucrose
	g.	%	%	%	%	%	%	%	%
Biasong...	52	28	7	22	44	8.93	7.57	0.06	0.00
Ganid.....	135	28	6	29	37	8.21	4.61	0.55	0.00
Camisan...	141	23	3	20	54	10.81	2.38	4.66	0.16
Lambog...	72	29	6	25	40	9.08	6.05	0.00	0.00
Suangui...	64	36	5	27	32	10.42	6.21	0.06	0.00

WHITE SAPOTE

Casimiroa edulis Lalave et Lex.

The white sapote, long cultivated in the highlands of Mexico and Central America and recently introduced here and there in the Mediterranean region, California, and Florida, is, however, not generally known. It belongs to the same family as the orange, but the sweet flavor suggests the peach rather than the well-known citrous fruits.

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[1] J. Biol. Chem. 1928, **78**, 215.

[2] Ibid. 1929, **82**, 465.

[3] Philippine J. Sci. 1925, **28**, 45.

MACROSCOPIC STRUCTURE.—The *fruit* is several centimeters in diameter, round, green-yellow, with oval seeds, 2 to 3 cm. in length, consisting largely of two large flat cotyledons.

MICROSCOPIC STRUCTURE.—The edible tissues were not available but the histology of the seed and the closely enveloping endocarp is as follows:

Pericarp.—The *endocarp* is made up of sclerenchyma fibers or elongated stone cells, running from the point of attachment up the back and spreading out diagonally over the whole surface of the seed.

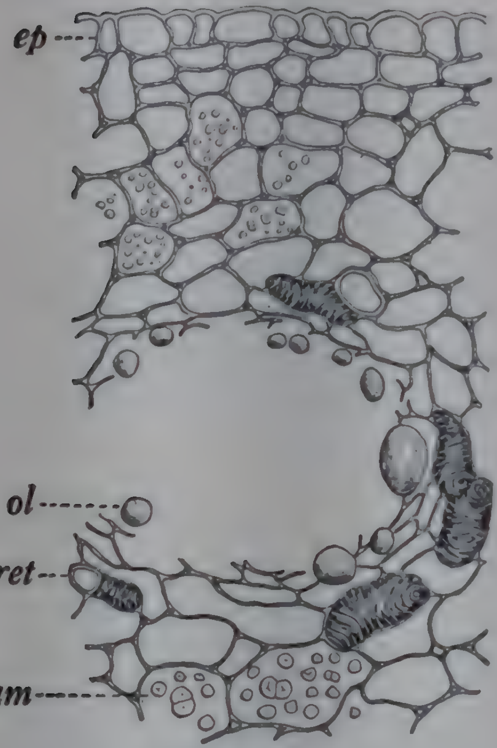

FIG. 245.—White Sapote. Cotyledon in cross section. *cp* outer epiderm; *ol* oil drop; *ret* reticulated cells; *am* starch grains. × 160. (K.B.W.)

Spermoderm, a thin brown tissue, adhering closely and conforming to the shape of the embryo is made up of characterless, thin-walled, compressed cells through which runs the raphe.

Perisperm and **Endosperm.**—Not present.

Embryo.—The *cotyledons* (Fig. 245) consist of (1) epiderm (*ep*) of small cells, (2) thin-walled starch parenchyma, with rounded starch grains (*am*), up to 11 μ, in small aggregates, forming the bulk of the tissue, and (3) oil cavities (*ol*) surrounded by thin-walled cells interspersed with spiral-reticulated cells (*ret*) about twice as long as broad.

CHEMICAL COMPOSITION.—No analysis of the fruit is available but an analysis of the seed made at the University of California shows: water 72.64, protein 0.64, fat 0.46, invert sugar 8.44, sucrose 12.20, starch 3.92, and fiber 1.26 per cent.

FRUITS OF THE MAHOGANY FAMILY

(*Meliaceæ*)

Two tropical fruits, langsat and santol, belong in this family.

COMPARATIVE MACROSCOPIC STRUCTURE.—Both fruits have five locules and a densely hairy epicarp. In the langsat the pericarp forms a thin rind, the edible part being the fleshy arils, whereas in the santol the inner mesocarp is fleshy and edible, arils being absent.

COMPARATIVE MICROSCOPIC STRUCTURE.—Volatile oil cavities occur in the mesocarp of both species and in the cotyledons of langsat. The cotyledons of both are starchy.

COMPARATIVE CHEMICAL COMPOSITION.—Both fruits are moderately saccharine and agreeably acid.

LANGSAT

Lansium domesticum Jack

Ger. Lansa.

Popenoe[1] states that the fruit of this species, although inferior to the mangosteen, is one of the best grown in the Malayan region. In the Philippines it is variously known as lanzone, lansóne, and bóboa. Duku is the name of a variety with larger fruit grown in smaller clusters.

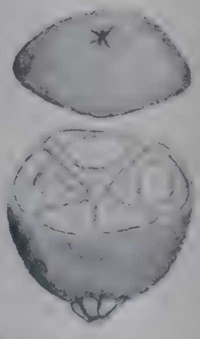

Fig. 246.—Langsat. Fruit, cut transversely, showing the five locules each containing a jelly-like aril surrounding perfect or abortive seed. ×½. (A.L.W.)

MACROSCOPIC STRUCTURE.—Sepals, petals, and cells of the ovary number five and the stamens ten, forming a tube. The round or elongated *fruit* (Fig. 246) of the common form ranges up to 3 cm. long, of the duku up to 5 cm. Sepals persist at the base. A thin rind, consisting of the velvety russet-colored epicarp, the mesocarp, and the endocarp, and the still thinner partitions between the five locules separate readily from the fleshy *arils* which are the edible part and form the bulk of the whole fruit. Usually only one (or two) of the arils contains a well-developed *seed* which is about the size of a small almond. The spermoderm and endosperm form a thin skin over the straight embryo consisting of two fleshy cotyledons and a short radicle.

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[1] Manual Trop. Subtrop. Fruits, New York, 1920, p. 426.

MICROSCOPIC STRUCTURE (Fig. 247).—The **Pericarp** (*F*) consists of (1) small-celled *epicarp* (*epi*) with numerous short, pointed, thick-walled warty hairs, also jointed capitate hairs; (2) *hypoderm* of characterless cells passing into (3) *mesocarp* (*mes*) through which are distributed volatile oil cavities and, in the outer part, small groups of stone cells (*st*); and (4) *endocarp* (*end*) of thin-walled, tangentially elongated, often crossing cells, in two or more rows.

Aril (*A*).—As seen in cross section, the *outer* and *inner epiderms* (*ep*) are of broad but low cells with granular contents, while the *pulp cells* (*p*) are large and in the inner part radially elongated.

Spermoderm (*S*).—Three tissues are differentiated: (1) *outer epiderm* (*aep*) of striking, longitudinally elongated, thick-walled, spirally reticulated cells, grown fast to the inner epiderm of the aril; (2) *parenchyma* through which runs the raphe bundle (*fv*); and (3) *inner epiderm* (*iep*) of brown, thin-walled cells.

Endosperm (*E*).—In parts, this is well developed with one or more rows of thick-walled cells divided by thin partitions into daughter cells. The contents are finely granular.

Embryo.—Excepting the epidermal and subepidermal tissues which have somewhat thickened walls, the cells of the *cotyledon* (*C*) are thin-walled and contain minute, scarcely measurable, starch grains, (*am*), some in aggregates up to 12 μ in diameter. Small volatile oil cavities (r^2) occur here and there.

CHIEF STRUCTURAL CHARACTERS.—Fruit

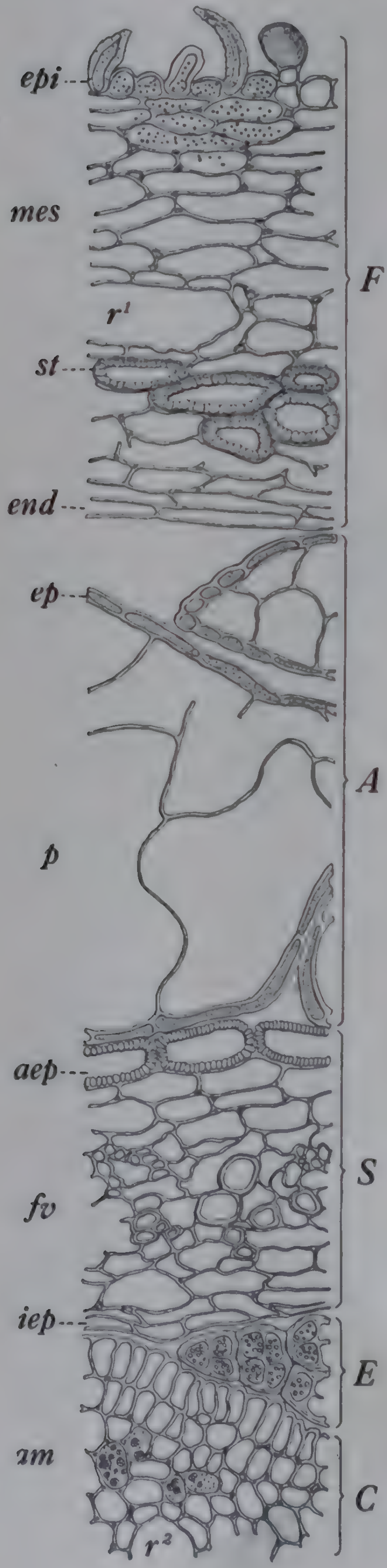

FIG. 247.—Langsat. Fruit and seed in cross section. *F* pericarp: *epi* epicarp with hairs, *mes* mesocarp with r^1 oil cavity and *st* stone cells, *end* endocarp. *A* aril: *ep* epiderm, *p* parenchyma. *S* spermoderm: *aep* outer epiderm, *fv* raphe bundle, *iep* inner epiderm. *E* endosperm. *C* cotyledon: *am* starch cells, r^2 oil cavity. × 160. (K.B.W.)

up to 5 cm.; epicarp velvety pubescent; rind thin; locules five, each with fleshy, edible aril, not all with perfect seeds.

Epicarp hairs partly short, pointed, thick-walled, warty, partly jointed, capitate; mesocarp with stone cells groups and volatile oil cavities; endocarp cells tangentially elongated. Aril of large cells. Spermoderm with spirally reticulated, thick-walled outer epiderm. Endosperm of thick-walled cells divided into daughter cells. Cotyledons containing minute starch grains, some in aggregates up to 12 μ.

CHEMICAL COMPOSITION.—The edible fruit pulp of samples grown in the Philippines, as analyzed by Pratt and Del Rosario [1] and by Adriano,[2] contained as follows:

Composition of Langsat Pulp

	Pulp in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
P. and Del R.†	80	19.9	1.6	1.13	....	1.00	4.90	8.01	....	0.59	64
Adriano:											
I.	59	13.3	...	0.76	0.14	....	....	....	0.44	0.65	..
II.	75	14.4	...	1.22	0.60	....	....	....	0.70	....	..

* Cc. $N/10$ acid per 100 grams pulp. † Weight of fruit 20 grams.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan [3] reports 1.10 per cent, dry basis, in the edible portion.

SANTOL

Sandoricum Koetjape (Burm.) Merr. = *S. indicum* Cav.

Like its relative the langsat, this fruit is a native of Malaysia. According to Pratt and Del Rosario, it is grown in large quantities throughout the Philippines and is eaten raw or cooked with sugar and candied to make "santol paste."

MACROSCOPIC STRUCTURE.—The nearly globular *fruit* reaches 5 cm. or more in diameter. It has a tan-colored hairy epicarp forming with the outer mesocarp a thick hard rind. The jelly-like inner mesocarp, extending to the center of the fruit in five rays, is the edible portion. A thin but tough endocarp lines each of the five locules in which is suspended a *seed*, without an aril, reaching 2.5 cm. in length. The straight embryo consists largely of the two fleshy cotyledons.

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[1] Philippine J. Sci. 1913, **8**, 59.

[2] Philippine Agr. 1925, **14**, 57.

[3] Ibid., 1932, **21**, 53.

MICROSCOPIC STRUCTURE. Pericarp.—The structure differs from that of the langsat in that (1) the pointed *epicarp* hairs are thicker-walled and longer, often over 200 μ, (2) *mesocarp stone cells* are lacking, and (3) the *mesocarp pulp cells* are thicker-walled in the outer part and thin-walled in the inner (edible) part.

Spermoderm.—Cells brown, characterless, and not well differentiated.

Embryo.—The *cotyledons* contain numerous rounded, truncated, or angular starch grains, up to 8 μ, some of which are in aggregates. Volatile oil cavities, such as are present in the langsat, are lacking, but numerous cells, especially toward the periphery, are of a bright yellow color due to resinous contents.

Chief Structural Characters.—See Langsat.

CHEMICAL COMPOSITION.—The edible fruit pulp of samples grown in the Philippines, as analyzed by Pratt and Del Rosario [1] and by Adriano, Manahan, and Barros,[2] contained as follows:

Composition of Santol Pulp

	Pulp in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
P. and Del R.†	70	20.30	6.4	0.86	....	1.35	3.08	1.66	....	0.98	70
A. M. and B.	61	13.56	...	0.91	1.43	....	....	....	2.30	0.78	

* Cc. $N/10$ acid per 100 grams pulp. † Weight of fruit 85 grams.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan [3] found about 0.43 per cent, dry basis, in the edible portion.

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[1] Philippine J. Sci. 1913, **8**, 59.

[2] Philippine Agr. 1929, **18**, 119.

[3] Ibid. 1932, **21**, 53.

FRUITS OF THE SPURGE FAMILY

(*Euphorbiaceæ*)

Two succulent fruits, emblic and bignay, are described. The Otaheite gooseberry (not described) belongs to the same genus as emblic. The castor bean (*Ricinus communis* L.) and the candlenut (*Aleurites moluccana* Willd.) are members of the same family.

COMPARATIVE MACROSCOPIC STRUCTURE.—Bignay is a drupe, emblic a stone fruit with three locules, each containing two triangular seeds. The seeds of both species have a bulky endosperm and axial embryo.

COMPARATIVE MICROSCOPIC STRUCTURE.—Neither fruit shows evidence of latex tubes in the pericarp or conspicuous crystalloids in the endosperm which are characteristics of some members of the family. In both the mesocarp contains scattered stone cells and the endocarp consists largely of stone cells.

COMPARATIVE CHEMICAL COMPOSITION.—Bignay is strongly acid and non-saccharine. Analyses of the other species are not available.

BIGNAY

Antidesma Bunius Spreng.

According to Pratt and Del Rosario, this agreeably acid fruit is plentiful in all parts of the Philippines and is eaten with fish. The tree is diœcious and a native of Malaysia.

MACROSCOPIC STRUCTURE.—The numerous greenish *flowers* and the red fruits are borne in spikes. Each *fruit* is a nearly globular drupe, about 12 mm. in diameter, crowned with the remains of the styles. The *stone* is pointed, has two sharp edges, and is wrinkled on the two sides. It contains a single locule with only a single anatropous *seed* in the specimens examined, although the ovary is stated to be two-ovuled. The straight embryo is central in the bulky endosperm.

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* of isodiametric, faintly beaded cells, with colored contents, also occasional stomata; (2) *mesocarp* of rounded, often somewhat radially elongated, pulp cells and in the inner part a few rounded, rather thin-walled stone cells containing a brown substance; and (3) *endocarp* of stone cells, in the outer part branching and interlocking, in the inner part of simpler form and longitudinally elongated, also numerous thin-walled cells each containing a single oxalate crystal.

The **Spermoderm** is much simpler in structure than that of emblic and castor bean. Only three layers are present: (1) *outer epiderm* of thin-walled, brown cells somewhat tangentially elongated; (2) *colorless cells,* several thick, tangentially elongated, often crossing, and distinctly beaded as seen in surface view, among which run the raphe bundles; and (3) *brown cells* with thin walls.

Endosperm.—The tissue is bulky and consists of *aleurone cells.*

Embryo.—The thin *cotyledons* consists of small cells and procambium bundles with characterless contents.

CHIEF STRUCTURAL CHARACTERS.—Fruit small (12 mm.), drupaceous; stone wrinkled, with two sharp edges, one-celled, one-seeded; endosperm bulky. Seed anatropous; embryo central with thin cotyledons.

Mesocarp with thin-walled stone cells; endocarp of (1) branching and interlocking stone cells, (2) simple stone cells, and (3) thin-walled cells with single oxalate crystals. Spermoderm simpler than in emblic. Endosperm and embryo characterless, starch-free.

CHEMICAL COMPOSITION.—The fruit flesh of a sample grown in the Philippines, as analyzed by Pratt and Del Rosario,[1] contained as follows:

COMPOSITION OF BIGNAY PULP

Weight	Pulp in fruit	Solids	Protein	Acids as citric	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
g.	%	%	%	%	%	%	%	cc.
0.3	80	5.2	0.75	2.78	0.00	0.00	0.78	96

* Cc. $N/10$ acid per 100 grams pulp.

EMBLIC

Phyllanthus Emblica L. = *Emblica officinalis* Gaertn.

Ger. Graue Myrobalanen.

The tree is a native of Asia but is cultivated in Puerto Rico and other tropical regions. The fruit is eaten out of hand or preserved. Since the leaves and bark are rich in tannin the tree is sometimes known as myrobolan. The species, however, should not be confused with small or Madras myrobolan (*Terminalia Chebula* Retzius = *Myrobalanus*

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[1] Philippine J. Sci. 1913, 8, 59.

Chebula Gaertn.) and large or Bombay myrobolan (*Terminalia citrina* Roxb.), the fruits of which are not edible but are used in tanning. The Otaheite gooseberry (*Phyllanthus acidus* Skeels) yields fruit used for pickling and preserving.

MACROSCOPIC STRUCTURE.—In this genus the apetalous *flowers* are on the plan of three, with usually three stamens, styles, and cells of the ovary, but often twice that number of sepals. The *fruit* of the emblic is apple-shaped, 2 to 3 cm. in diameter. The *stone* is hexagonal with slightly incurved sides and contains three diamond-shaped locules formed by three partitions extending from alternate angles to the center. Each locule is completely filled by two triangular *seeds* with a thin, brown, mottled spermoderm, a bulky endosperm, and a central embryo. An inconspicuous caruncle covers the micropyle.

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* of rounded, polygonal, rather thick-walled cells, showing beads on treatment with sodium hydroxide, and occasional stomata; (2) *mesocarp* of characterless, rounded pulp cells interspersed toward the endocarp with fibro-vascular bundles and rounded stone cells, and in the very innermost portion with radiating bundles of narrow, elongated, very thick-walled stone cells; and (3) *endocarp*, 200 to 300 μ thick, of a dense tissue of stone cells, radially elongated in the middle part, with yellow-brown contents.

Spermoderm.—The structure resembles that of the spermoderm of the castor bean, the layers being: (1) *outer epiderm* of rounded-polygonal, brown cells with irregularly thickened walls; (2) *subepiderm* of transversely elongated, thin-walled cells; (3) *sclerenchyma cells*, radially (125 μ) and longitudinally elongated, with narrow lumen, forming a palisade layer; (4) *cross cells* similar to those of the subepiderm but longer; and (5) *brown cells* one or two thick. A narrow band of compressed cells within the fifth layer may belong to the spermoderm or the perisperm.

Endosperm.—Typical *aleurone cells*, containing small aleurone grains and oil, form the bulk of the seed.

Embryo.—The tissues are characterless.

CHIEF STRUCTURAL CHARACTERS.—Fruit apple-shaped, 2 to 3 cm., with hexagonal three-loculed stone, each locule containing two triangular seeds.

Mesocarp with (1) rounded and (2) narrow, radially elongated stone cells; endocarp of stone cells. Spermoderm with five layers, the third of sclerenchyma cells forming a palisade layer. Endosperm of aleurone cells.

FRUITS OF THE CASHEW FAMILY

(*Anacardiaceæ*)

Several trees of this family yield edible fruits or seeds. In the mango, also ambarella, red mombin, and other species of *Spondias*, it is the mesocarp that is edible; in the pistachio and cashew nuts (see Volume I) it is the cotyledons; and in the cashew apple it is the fleshy peduncle.

The non-edible mesocarp of the cashew nut contains the same toxic principles as poison sumac and poison ivy (*Rhus*).

COMPARATIVE MACROSCOPIC STRUCTURE.—The *flowers* are normally on the plan of five but the superior ovary and the *fruit* of pistachio, mango, and cashew are one-loculed.

COMPARATIVE MICROSCOPIC STRUCTURE.—Elongated *oleoresin passages* occur in the mesocarp and cotyledons of mango, cashew, and species of *Spondias*, and in the peduncle of cashew (cashew apple). These are oval in cross section, encircled by flattened cells, and are apparently lysigenic except in the cotyledon of cashew where they are irregular in shape, surrounded by palisade cells, and apparently schizogenic.

Starch and *chromatophores* occur in the mesocarp of mango and starch in the mesocarp of species of *Spondias*.

All the species have a hard and stony or leathery *endocarp* which consists largely of thick-walled fibers running into the mesocarp (mango, red mombin), of thick-walled fibers and stone cells (ambarella), of branching, interlocking stone cells (pistachio), or of palisade cells (cashew).

A thin but distinct *endosperm*, with usually one or more rows of aleurone cells and a compressed tissue, is present in all the species but mango.

Elongated *starch grains* abound in the cotyledons of mango and cashew. Traces of starch are present in the cotyledons of pistachio but only *aleurone grains* in the species of *Spondias*. Starch abounds in the cashew apple.

COMPARATIVE CHEMICAL COMPOSITION.—The edible portion of the fruits of this group is moderately or highly saccharine and of low acidity. The nature of the volatile oil that contributes a marked flavor to the mango is a subject for study.

MANGO

Mangifera indica L.

Fr. Mangue. Sp. Mango. It. Mango. Ger. Mango.

De Candolle presents conclusive evidence that the mango is a native of India, where it has been cultivated since prehistoric times. Popenoe[1] divides the varieties, which differ as much as those of the apple in form, size, coloration, and flavor, into four groups. In addition to being rich in sugar and acid, the fruit has a peculiar aromatic flavor due to a volatile (essential) oil found in special oleoresin cavities which, taken in conjunction with the fibrous strands distributed through the flesh, give the fruit characters quite distinct from those of other fruits. When well ripened, it is a delicious dessert fruit and used green or ripe makes good salads. It retains reasonably well its flavor on canning and preserving.

The mango was introduced toward the end of the nineteenth century into Florida and California where it is now successfully grown and shipped to northern centers but as yet is not generally known and appreciated.

MACROSCOPIC STRUCTURE.—Numerous flowers are borne in panicles of which only a small percentage is perfect, the remainder being staminate. Each *flower* is less than 1 cm. in diameter, the five blunt petals being twice the length of the five pointed sepals, all arising from the base of a raised disk. The petals are further distinguished by orange ridges near the base. Only one perfect stamen, borne inside the disk, is ordinarily developed. The small one-celled ovary has a lateral style.

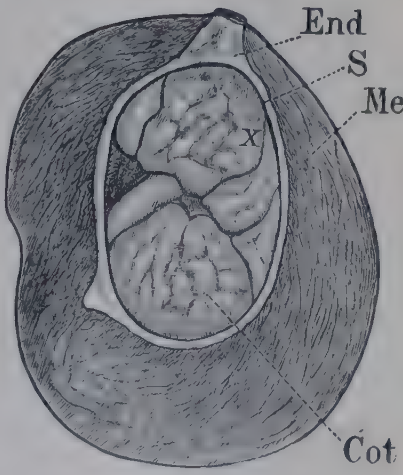

FIG. 248.—Mango. Fruit. Longitudinal section. *Mes* mesocarp (fruit flesh) with fibers; *End* endocarp (stone); *S* spermoderm; *Cot* cotyledons entire. The small radicle directed upward is beneath *x*. × ½. (A.L.W.)

The *fruit* (Fig. 248) is a drupe, varying up to more than 15 cm. long. It is unsymmetrical with excentric, rounded or tapering base and excentric, rounded or beaked apex. When not beaked, the apex is recognized by the scar of the style. The surface is smooth, varying in color from green to yellow, sometimes with a red cheek, according to variety, and indistinctly spotted by oil passages of the mesocarp. The *stone* is flattened and covered with a mass of loose fibers which grow into the succulent mesocarp. Within the stone, a thin lustrous, irregularly streaked spermoderm encloses the much-distorted and folded, fleshy embryo or, in the case of the polyembryonic cambodiana group, normally two or more embryos.

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[1] Manual Trop. Subtrop. Fruits, New York, 1920, p. 80.

MICROSCOPIC STRUCTURE.—Griebel[1] describes tissues of the pericarp and seed. Our studies were made on material furnished by Professor Cowles, University of Puerto Rico.

Pericarp (Fig. 249).—Five layers are well marked: (1) *epicarp* (*epi*) of small cells with much-thickened walls and cuticle and rounded lumen; (2) *hypoderm* (*hy*) of large cells in several rows with thick porous walls, also oleoresin passages (*res*); (3) *mesocarp* (*mes*) of sac-like pulp cells containing occasional starch grains and orange chromatophores, also oleoresin passages and fibro-vascular bundles running from the endocarp; (4) *endocarp* of fiber and fibro-vascular bundles, extended in different directions, the fibers (*f*) being thick- and thin-walled and often grotesque, also accompanying crystal fibers with both single and rosette crystals (*cr*); and (5) *inner layer* or endocarp proper (*i*) of cells with thick, wavy, porous walls.

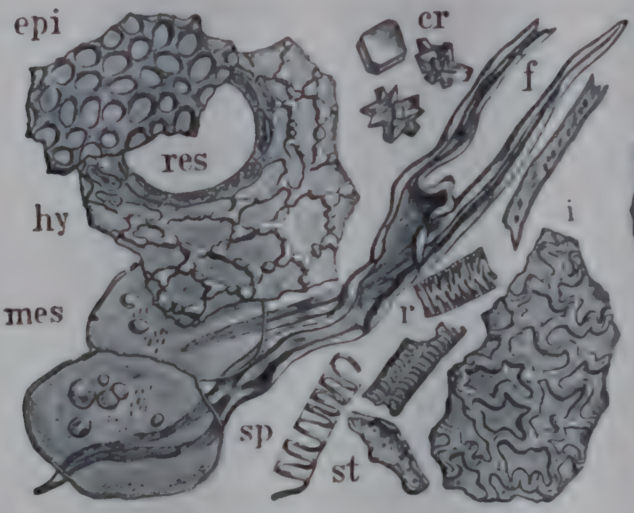

Fig. 249.

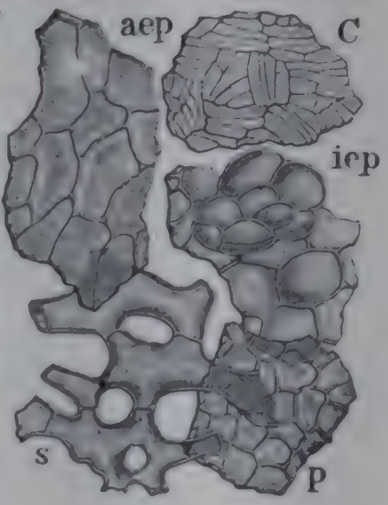

Fig. 250.

Fig. 249.—Mango. Elements of pericarp in surface view. *epi* epicarp; *hy* hypoderm with *res* oleoresin passage; *mes* mesocarp pulp cells with chromatophores and starch grains; *cr* endocarp crystals; *f* fibers; *sp* spiral vessel; *r* reticulated vessel; *st* stone cell; *i* inner layer. × 160. (K.B.W.)

Fig. 250.—Mango. Elements of seed in surface view. Spermoderm: *aep* outer epiderm, *s* spongy outer parenchyma, *p* inner parenchyma, *iep* inner epiderm. *C* epiderm of cotyledon. × 160. (K.B.W.)

The association of numerous fibers with pulp cells in the mesocarp gives the fruit its peculiar texture, the pulp cells being broken and torn away from the fibers on chewing.

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[1] Z. Unters. Lebensm. 1928, **55**, 89.

Spermoderm (Fig. 250).—There are four layers: (1) *outer epiderm* (*aep*) of delicate cells seen on staining; (2) *spongy parenchyma* (*s*); (3) *normal parenchyma* (*p*), compressed in the inner portion; and (4) *inner epiderm* (*iep*) of thin-walled, polygonal cells, often extended inward as short papillæ or rounded multicellular groups.

Endosperm.—Not evident.

Embryo.—The *outer epiderm* (Fig. 250, *C*) of the cotyledon consists of narrow parquetted cells. The *mesophyl* is characterized by starch grains and oleoresin passages. The starch grains (Vol. I, Fig. 35) are mostly elongated, oval or kidney-shaped, up to 40 μ long, with an elongated rift. Examined under the polarization microscope, one dark line of the cross follows the rift, the other crosses at right angles, thus differing from leguminous starches. Small grains united as twins and other small aggregates are also present.

CHIEF STRUCTURAL CHARACTERS.—Epicarp smooth, position of excentric style marked by a spot or beak; mesocarp with numerous oleoresin passages and bundles; endocarp hard with hair-like protruding bundles. Spermoderm thin, smooth. Cotyledons fleshy, distorted.

Mesocarp cells rounded with occasional starch grains and chromatophores; bundles of mesocarp and endocarp of fibers only and of fibers surrounding vascular elements and crystal fibers. Spermoderm characterless. Cotyledons with epiderm of narrow parquetted cells and mesophyl containing elongated starch grains up to 40 μ and oleoresin passages.

CHEMICAL COMPOSITION.—The composition of the edible fruit flesh of mangos grown in the West Indies is well illustrated by 4 analyses made by Cousins [1] and 9 analyses made by Chace, Tolman, and Munson.[2] Pratt and Del Rosario [3] made 3 analyses, Adriano, Monahan, and Barros,[4] one analysis of fruit grown in the Philippines; and Thompson,[5] 8 analyses of fruit grown in Hawaii. The results appear in the table on the next page.

Respiration.—Gore,[6] working with 4 samples of the variety Turpentine, noted a maximum evolution of 192 mg. of carbon dioxide per kilo per hour at 34.4° C. and a minimum of 6 mg. at 2.3° C.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan [7] reports in

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[1] Jamaica Dept. Agr. Bul. 1903, **1**, II, 263.

[2] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[3] Philippine J. Sci. 1913, **8**, 59.

[4] Philippine Agr. 1929, **18**, 119.

[5] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[6] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[7] Philippine Agr. 1932, **21**, 53.

Composition of Mango Flesh

	Flesh in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
Cousins:											
Min.	54	15.33	0.82	....	....	1.37	2.38	6.78	....	0.20	..
Max.	65	22.35	1.18	....	....	1.51	5.26	10.83	....	0.38	..
Aver.	**58**	**18.80**	**1.02**	....	....	**1.44**	**3.72**	**8.81**	....	**0.32**	..
C. T. and M.:											
Min.†	48	10.23	0.82‡	0.32‡	....	0.13	1.72	6.34	....	0.35	16
Max.†	78	21.72	3.70‡	0.70‡	....	0.55	6.14	11.60	....	0.78	91
Aver.†	**63**	**16.76**	**1.76‡**	**0.43‡**	....	**0.39**	**3.56**	**10.06**	....	**0.47**	**47**
P. and Del R.:											
Min.§	60	17.2	2.6	0.22	....	0.18	2.00	8.49	....	0.40	53
Max.§	73	25.7	8.1	1.12	....	0.32	4.22	14.78	....	0.53	57
Aver.§	**69**	**22.3**	**4.5**	**0.73**	....	**0.27**	**3.27**	**12.60**	....	**0.46**	**55**
A. M. and B.	75	12.67	...	0.69	0.08	....	....	.....	0.93	0.38	..
Thompson:											
Min.	60	15.27	1.75	0.44	0.03	0.17	1.53	7.93	0.40	0.27	..
Max.	70	23.42	5.88	1.08	0.53	0.83	4.55	16.99	0.72	0.47	..
Aver.	**64**	**20.07**	**3.44**	**0.71**	**0.15**	**0.42**	**3.16**	**12.09**	**0.59**	**0.39**	..

* Cc. $N/10$ acid per 100 grams fruit. † Weight of fruit 67 to 255, aver. **138** grams. ‡ 5 samples. § Weight of fruit 85 to 240, aver. **185** grams.

the flesh of the green and ripe fruit 1.07 to 2.71 and 1.79 to 2.55 per cent respectively, dry basis.

Colors.—Yamamoto and Yasuyoshi[1] isolated from the fruit flesh *carotene*, in crystalline form, identical with that of the carrot. The following amounts of pigments were found by Yamamoto, Osima, and Goma[2] in mango pulp: *carotene* (α and β) 0.0118 (melting point 179° C., $[\alpha]\frac{28}{C}$ 136° in CS_2), *xanthophyl esters* 0.0079, and *free xanthophyl* 0.0016 per cent on the dry basis.

Mineral Constituents.—Determinations by Chace[3] in the pulp of French and Filipino mangos and a third variety not specified show 0.53, 0.41, and 0.78 per cent of ash. Analyses of the ash appear below:

	K_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%
French	47.37	6.38	1.62	6.49	3.67	....	3.88
Filipino	51.79	1.74	3.25	9.04	4.88	1.75	1.56
Var. unknown	49.37	2.38	....	5.57	3.84	2.14	4.20

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[1] J. Agr. Chem. Soc. Japan 1931, **7**, 320.

[2] Sci. Papers Inst. Phys. Chem. Res. (Tokyo) 1932, **19**, 122.

[3] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

AMBARELLA

Spondias cytherea Sonn. = *S. dulcis* Forst.

Fr. Pomme cythere. Port. Cajá-manga.

Popenoe [1] prefers the name ambarella, used in Ceylon, to Otaheite-apple, current in some English colonies. This species, a native of Polynesia, is widely cultivated in the tropics and sub-tropics.

MACROSCOPIC STRUCTURE.—The polygamous white *inflorescence* is similar to that of the mango but the ovary has normally five one-ovuled locules and as many styles.

The *fruit* is a drupe, the largest of the common species, reaching 8 cm. in length, and is yellow in color. Closely grown to the mesocarp is the light brown *stone* with five locules, the woody tissue over each forming a longitudinal ridge bristling with narrow, sharp, spreading spines, suggesting somewhat the butternut.

In each locule is a single *seed*, consisting of a thin spermoderm and endosperm and a straight embryo with fleshy cotyledons and short radicle.

MICROSCOPIC STRUCTURE. Pericarp.—The tissues may be grouped into five layers: (1) *epicarp* of small, rounded, thick-walled cells and occasional stomata; (2) *hypoderm* of several rows of thick-walled, indistinctly porous cells of increasing size; (3) *mesocarp* of thinner-walled, rounded pulp cells, containing numerous starch grains, also many irregularly distributed oleoresin cavities and, especially in the inner part, fibro-vascular bundles; (4) *endocarp* made up of thick-walled fibers, especially abundant in the spines and in the inner portion where they are transversely elongated, also rounded stone cells, each containing a single large oxalate crystal; and (5) *inner layer* of somewhat thickened, wavy-walled cells.

The *starch grains* are large, irregularly ellipsoidal, up to 55 μ long, with a somewhat excentric hilum, often crossed by a rift, or small occurring in small aggregates.

Especially noticeable are the oleoresin passages, which do not occur in the hypoderm, and are not limited to a single row in the mesocarp.

Spermoderm.—This is thin consisting of (1) *outer epiderm* with thin, indistinctly beaded walls and dark brown contents and (2) *compressed parenchyma* forming several rows.

The **Endosperm** is thicker than the spermoderm and consists of (1) several rows of *aleurone cells* with small aleurone grains and (2) *compressed parenchyma.*

---

[1] Manual Trop. Subtrop. Fruits, New York, 1920, p. 155.

Embryo. *Cotyledons.*—Beneath an outer epiderm of longitudinally elongated cells is the mesophyl consisting of small cells, containing minute aleurone grains, and distributed among these cells occasional oleoresin passages.

Chief Structural Characters.—Fruit large with spiny endocarp and five locules. Spermoderm and endosperm thin. Embryo straight with fleshy cotyledons and small radicle.

Mesocarp of pulp cells containing ellipsoidal starch grains up to 55 μ with excentric hilum and oleoresin passages; endocarp made up of fibers and rounded stone cells each with a large single crystal. Spermoderm and endosperm characterless. Cotyledons composed of ground tissue containing minute aleurone grains and occasional oleoresin passages.

CHEMICAL COMPOSITION.—Thompson[1] analyzed the edible part of the ambarella (*S. cytherea*), known in Hawaii as wi apple, and of the hog plum (*S. lutea*). Pratt and Del Rosario[2] analyzed the edible part of the red mombin (*S. Mombin*), known in the Philippines as *cirihuelas.* All available data on the group are here tabulated:

Composition of Flesh of Spondias Fruits

	Flesh in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as tartaric	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc
Ambarella....	65	14.53	2.48	0.50	0.29	0.73	7.09	3.45	0.85	0.44	..
Red mombin†	50	13.00	4.30	0.63	....	0.53	8.08	5.97	....	0.27	27
Hog plum....	48	11.47	0.83	1.38	0.57	1.50	9.41	0.00	1.17	0.66	..

* Cc. *N*/10 acid per 100 grams pulp. † Weight 20 grams.

RED MOMBIN

Spondias Mombin L. = *S. purpurea* Mill.

Fr. Mombin rouge. Sp. Ciruela. Ger. Mombinpflaume.

This fruit, also known as the Spanish plum, is a native of tropical America. It is eaten fresh, dried, and cooked.

MACROSCOPIC STRUCTURE.—Both the *flowers* and the *fr* are purple, the latter resembling in size a large olive. The *stone*, s rated from the mesocarp, is not so spiny as that of the ambarella. —

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[1] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[2] Philippine J. Sci. 1913, **8**, 59.

samples examined were without perfect seeds, although spermoderm tissues were occasionally present.

MICROSCOPIC STRUCTURE.—The structure of the **Pericarp** differs from that of the ambarella chiefly in that (1) the *mesocarp* pulp cells are radially much elongated, thin-walled, and contain rounded starch grains, up to 25 μ, with central hilum, and (2) the *endocarp* consists of fibers with few if any stone cells.

The **Spermoderm** is thin and brown and only the outer epiderm is well differentiated but the walls of that layer are more distinctly beaded than in ambarella.

CHIEF STRUCTURAL CHARACTERS.—Distinction from ambarella noted above.

CHEMICAL COMPOSITION.—See Ambarella.

CASHEW APPLE

Anacardium occidentale L. = *Cassurium pomiferum* Lam.

Fr. Acajou. Sp. Marañon. It. Anacardo. Ger. Kaschu.

The general characters of this species, also the structure and composition of the pericarp and seed (nut), are described in Volume I.

The cashew apple is highly aromatic and agreeably astringent. From it are prepared preserves, punches, and wine. The tree yields timber and a varnish used as an insecticide.

MACROSCOPIC STRUCTURE.—The cashew apple (Fig. 226, Volume I) is unique among fruits in that it is morphologically the enlarged *peduncle* or fruit stalk, considered by some to be receptacle. It is bright yellow or scarlet, up to more than 8 cm. long.

MICROSCOPIC STRUCTURE. Peduncle ("Fruit").—Cross sections (Fig. 251) bring out (1) *epiderm* of isodiametric or somewhat elongated polygonal cells, up to 25 μ, but no stomata; (2) *hypoderm* of several rows of starch-free cells; and (3) *starch parenchyma* (*am*) in which are oleoresin cavities (*ol*), up to 500 μ, or more, surrounded by flattened cells, and fibro-vascular bundles in a mass of elon-
ted cells.

The *starch grains* are mostly round, up to
with a round central hilum and indistinct
Twins and triplets also are present, the

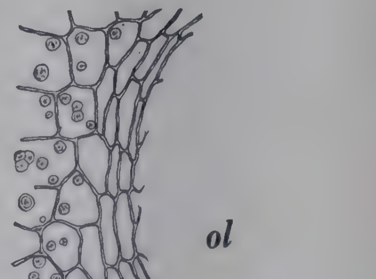

FIG. 251.—Cashew. Edible fruit flesh (peduncle) in cross section. *am* starch parenchyma; *ol* oleoresin cavity. × 160. (A.L.W.)

individuals showing, when separated, truncated surfaces of contact. Brilliant crosses are formed with polarized light. The *oleoresin cavities* are larger than in myrtaceous fruits but not so numerous. They are irregularly distributed throughout the tissue. A mass of narrow, elongated, parallel-walled cells makes up the bulk of the tissue in and about the *fibro-vascular bundles.* The vascular elements are large, up to 45 μ, spiral or spirally reticulated vessels. Double and loosely wound spirals are noticeable.

Chief Structural Characters.—Peduncle fleshy, red or yellow, up to 8 cm. long.

Epiderm of polygonal cells without stomata; parenchyma containing round or truncated starch grains, up to 15 μ; oleoresin cavities up to 500 μ; bundles accompanied by mass of elongated cells.

CHEMICAL COMPOSITION.—A specimen of cashew apple from Cuba analyzed by Chace, Tolman, and Munscn [1] and one from the Philippines analyzed by Pratt and Del Rosario [2] contained as follows:

Composition of Cashew Apple Flesh

	Weight	Flesh in fruit	Solids, total	Solids, insol.	Protein	Acids as malic	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	%
Cuban....	70	86	12.84	...	....	0.42	6.37	0.39	0.36	30
Philippine.	88	90	14.0	2.5	0.71	0.32	10.28	0.31	0.37	34

* Cc. $N/10$ acid per 100 grams fruit.

Srinivasan [3] calls attention to the high content of sugar and the practicability of preparing syrup from culls. The juice of one sample contained dry matter 10.4 and sugar (chiefly invert) 9.8 per cent.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Philippine J. Sci. 1913, **8**, 59.

[3] J. Indian Inst. Sci. 1934, **17A**, 85.

FRUITS OF THE SOAPBERRY FAMILY

(*Sapindaceæ*)

In addition to the litchi and longan, considered below, the rambutan (*Nephelium lappaceum* L.) and the pulasan (*N. mutabile* Bl.), both natives of Malayasia, as well as other related species, yield fruits with succulent arils.

COMPARATIVE MACROSCOPIC STRUCTURE.—The *calyx* is four- to five-toothed, lobed, or parted; *petals* may be present or absent; the *ovary* commonly is three-lobed and each lobe one-ovuled but the bladdery *fruit* is one-seeded. Only the *aril* has food value. Excepting an opening at the top this completely envelops the seed. The *seed*, or its embryo, is often abortive. When present it is anatropous with a thick spermoderm but without endosperm.

COMPARATIVE MICROSCOPIC STRUCTURE.—The aril consists of tissues characterized by their elongated (sometimes up to more than 1 mm.) form and more or less beaded walls. Visible contents are characterless.

COMPARATIVE CHEMICAL COMPOSITION.—The arils are highly saccharine and scarcely at all acid. Both *reducing sugar* and *sucrose* are present.

LITCHI

Litchi chinensis Sonn. = *Nephelium Litchi* Camb.

Ger. Litchipflaume.

Various phonetic spellings have been given for the name of this fruit, as is often true of distinctly oriental products. Authorities agree that the species is indigenous to southern China. The fruit is at its best when fresh although much used dried and canned, especially in the Chinese Quarters of American cities. The dried fruit is often known as litchi nut, which is a misnomer, since it is the succulent aril that is edible and not the dry endosperm or embryo.

MACROSCOPIC STRUCTURE.—Petals are lacking in the inconspicuous *flowers*; the calyx is several toothed. The *fruit* is red, becoming brown on drying. The pericarp (Fig. 252, I) is brittle and is characterized by the numerous short cones with polygonal bases which roughen the surface. Within the pericarp and free from it is the single seed (III) surrounded by the white, succulent, agreeably acid aril forming a sac with a small opening in the end. On drying the aril (II) becomes dark colored and changes somewhat in flavor.

The seed is stated by Popenoe[1] to be shriveled and not viable in some grafted varieties, but in seedlings it is as large as a good-sized castor bean. As shown in Fig. 252, III, the seed conforms to the latter description, being dark brown, lustrous, about 2 cm. long, with a hard stone-like spermoderm but without an evident embryo.

MICROSCOPIC STRUCTURE. Pericarp.—The tissues (not edible) are as follows: (1) *epicarp* of small polygonal cells, each containing a single oxalate crystal; (2) *stone cells*, one or more thick, characterized usually by their radial elongation and brown contents; (3) *mesocarp*, many cells thick, with ground tissue varying from rounded porous cells to spongy parenchyma, and fibro-vascular bundles; and (4) *endocarp* of two crossing layers of somewhat thickened elongated cells.

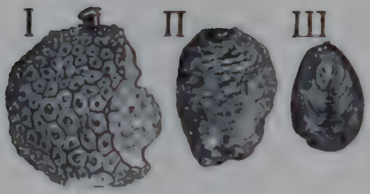

Fig. 252.

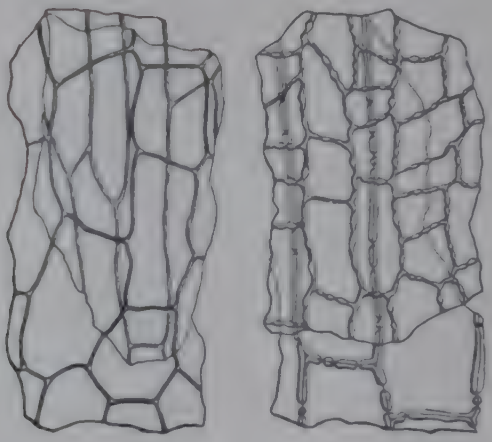

Fig. 253.

Fig. 252.—Litchi. I portion of pericarp (shell) after removal of seed. II seed enclosed in dried aril. III seed after removal of aril. × ½. (A.L.W.)

Fig. 253.—Litchi. Aril in surface view. Left: outer epiderm and subepiderm seen from without. Right: inner epiderm and adjoining layer seen from within. × 160. (K.B.W.)

Aril (Fig. 253).—The cells of the different layers are mostly longitudinally elongated and sometimes end to end in rows. In the middle layers they often reach the remarkable length of 1 mm. The cells o the *inner epiderm* have porous walls and those in the row immediately adjoining have strongly thickened and very distinctly porous walls.

Spermoderm.—The three brown layers are (1) *outer epiderm* o palisade cells, up to 40 μ high and half as broad, with porous, somewha thickened walls; (2) broad *middle layer* of cells with porous, thickened walls, the thickness diminishing inward, and raphe bundles; and (3) *inner epiderm* of small, transversely elongated, thin-walled cells.

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[1] Manual Trop. Subtrop. Fruits, New York, 1920, p. 322.

Endosperm.—Always absent.

Embryo.—Lacking in specimens examined.

Chief Structural Characters.—Pericarp red (brown on drying) with conical warts, polygonal at base. Aril fleshy; seed lacking or lacking embryo; spermoderm if present hard, lustrous.

Aril of more or less elongated cells, some reaching 1 mm. Inner layers with thickened and beaded walls.

CHEMICAL COMPOSITION.—Analyses of the edible portion (aril) of litchi nuts imported from China have been made by Blasdale[1] and by Read.[2] The arils of Blasdale's sample constituted 46 per cent of the whole nut and were obviously air dry.

	Water	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%
Blasdale	14.94	2.91	1.44	....	66.58	4.47	....	2.21
Read	40.80	....	....	0.21	52.90	0.00	0.40	....

Marloth[3] from small immature, medium, and large litchis obtained respectively: juice 50.5, 45.8, and 50.8 per cent; and in the juice, solids 18.3, 17.6, and 18.4, acid 1.6, 1.3, and 1.11 per cent, the solids-acid ratio being 11.2 : 1, 14 : 1, and 16.4 : 1.

LONGAN

Euphoria Longana Lam. = *Nephelium Longana* Camb.

Fr. Oeil de dragon. Ger. Drachenauge.

Among the various phonetic spellings for this fruit are long-yen, inkeng, lingeng, longyen, and yuenngan, the latter appearing on the abel of the canned fruit, packed in Canton, found on sale in the Chinese istrict of New York City.

The tree, believed to be indigenous to India, is much grown in China and the Malayan region, also to some extent in California and Florida. The fruit is considered less desirable than the litchi. It is eaten fresh, dried, and canned.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] J. Am. Chem. Soc. 1918, 40, 817.

[3] Farming S. Africa 1934, 9, 423, 438.

MACROSCOPIC STRUCTURE.—*Euphoria,* with its several species, is distinguished from *Litchi* by the five-parted calyx and the presence of a corolla. The *fruit* of the longan is buff or yellowish, usually somewhat smaller than that of the litchi.

MICROSCOPIC STRUCTURE.—In the structure of the aril the longan does not materially differ from the litchi. Such slight differences as have been noted may not hold for all specimens.

CHEMICAL COMPOSITION.—The edible portion (aril) of samples analyzed by Blasdale[1] and Thompson,[2] constituting respectively 40 and 58 per cent of the whole nut, contained as follows:

	Water	Protein	Fat	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%
Blasdale	10.94	5.01	1.04	27.34	37.50	....	2.31
Thompson	82.39	1.42	0.45	5.99	2.35	0.64	....

As in the case of the litchi nut, Blasdale's sample was obviously dried.

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1899, Bul. 68.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

FRUITS OF THE BUCKTHORN FAMILY

(*Rhamnaceæ*)

THE species yielding the highly saccharine, mildly acid edible drupes described below belong in one genus, *Zizyphus*.

CHINESE JUJUBE

Zizyphus Jujuba Miller. = *Z. vulgaris* Lam. = *Z. sativa* Gaertn.

Fr. Jujube. Sp. Azufaifa. It. Giuggiolo. Ger. Brustbeere.

Since very early times the jujube has been cultivated in China under the name *tsao*. Meyer,[1] who explored the fruit orchards of China, states that probably not less than one hundred varieties are cultivated there, the fruit being eaten dried, preserved in sugar, stewed, and smoked. A delicious sugared form, known as honey jujube, resembles in appearance the Persian date. Dried jujubes are sold in the Chinese Quarters of American cities.

Pliny writes that the tree was introduced into Europe during the reign of Augustus. Recently it has been introduced into the United States by the Bureau of Plant Industry.

The fruit of the Indian jujube or Indian fig (*Z. mauritiana* Lam. = *Z. Jujuba* Lam.) is orange; that of the lotus jujube (*Z. Lotus* (L.) Willd.) of northern Africa is smaller than the Chinese and Indian species. As is true of many cultivated plants, the species are not sharply marked.

MACROSCOPIC STRUCTURE.—Small five-merous, greenish or yellowish *flowers*, with usually two-loculed (seldom three- or four-loculed) ovary and two styles, characterize the genus. The fruit (Fig. 254) is a plum-shaped drupe, up to 2.5 cm. long, of a dark red or brown color. The stone (*end*) is furrowed. Of the two locules (*L*), one may contain a perfect seed (II), in which case that locule is larger than the other, but often both are empty (I). The endosperm (*E*) is thick on the sides, the embryo straight with thick cotyledons (*C*) and short radicle.

MICROSCOPIC STRUCTURE (Fig. 255).—The **Pericarp** (*F*) in section is seen to have six layers: (1) *epicarp* (*epi*) with thick outer walls and dark contents; (2) *hypoderm* (*hy*) of small flattened cells with yellow walls; (3) *mesocarp* (*mes*) of large, rounded, thin-walled, colorless pulp cells and, especially in the channels of the stone, delicate fibro-vascular bundles (*fv*); (4) *outer endocarp* of isodiametric stone cells (*st*), with colorless walls and yellow-brown contents, forming a thick, irregular layer; (5) *inner endocarp* of transverse fibers (*f*) in several rows; and (6) *inner layer* or endocarp proper (*end*) of thin-walled, yet porous, transversely elongated, cells.

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[1] U. S. Dept. Agr., Bur. Plant. Ind. 1911, Bul. **204**.

Spermoderm (*S*).—Three layers are present: (1) *palisade cells* (*pal*) with thick brown walls, a light line, narrow lumen expanding into a bulb in the center, and a broad cavity at the inner end; (2) *compressed parenchyma* (*p*), several cells thick; and (3) *inner epiderm* (*iep*) of small brown cells, conspicuous in surface view because of their nearly square form and thickened porous walls.

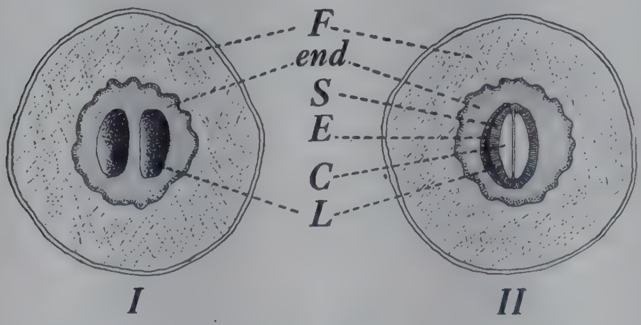

Fig. 254.

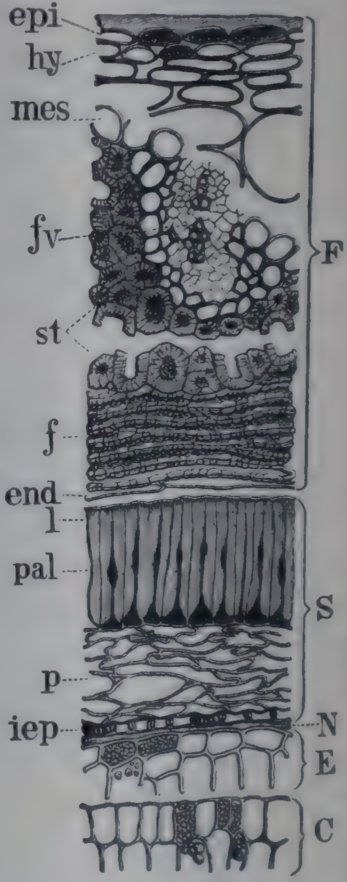

Fig. 255.

Fig. 254.—Jujube. Fruit in cross section, I without seed, II with seed. *F* fruit flesh; *end* endocarp; *S* spermoderm; *E* endosperm; *C* cotyledons; *L* empty locules. × 2. (K.B.W.)

Fig. 255.—Jujube. Fruit and seed in cross section. *F* pericarp: *epi* epicarp, *hy* hypoderm, *mes* mesocarp with *fv* fibro-vascular bundle, *st* stone cells of outer endocarp, *f* fibers of inner endocarp, *end* inner layer. *S* spermoderm: *pal* palisade cells with *l* light line, *p* compressed parenchyma, *iep* inner epiderm. *N* perisperm. *E* endosperm. *C* cotyledon. × 160. (K.B.W.)

In surface view the middle lamella of the *palisade cells* is beaded.

Perisperm (*N*).—A narrow structureless band.

Endosperm (*E*).—The cells have walls of medium thickness contain small aleurone grains and fat.

Embryo.—The cells of the *cotyledons* (*C*) are thin-walled contain small aleurone grains. Palisade cells occur beneath both derms.

Chief Structural Characters.—Fruit plum-like, dark red or brown; stone furrowed, two-loculed. Seeds one or more; endosperm thick on sides; cotyledons thick.

Mesocarp characterless; endocarp of stone cells and fibers. Spermoderm with palisade cells enlarged at center and base. Endosperm made up of aleurone cells.

CHEMICAL COMPOSITION.—Blasdale[1] gives the composition of the pulp of dried jujubes from the Chinese Quarter of San Francisco. Church[2] reports the results of physical and chemical examinations of the pulp of fresh and dried jujubes grown at the U. S. Plant Introduction Garden, Chico, California.

Composition of Jujube Pulp

	Samples	Water	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Pectin	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Blasdale:										
Dried.....	1	13.44	2.93	....	....	42.19	13.06	....	....	1.73
Church:										
Fresh.....	10*									
Min.....		60.06	0.90	0.26†	0.27	5.92	0.00	0.17‡	0.87	0.74
Max.		73.96	1.55	0.30†	0.54	22.10	20.20	0.49‡	1.69	1.02
Aver....		**65.36**	**1.16**	**0.28†**	**0.43**	**11.91**	**12.22**	**0.36‡**	**1.27**	**0.85**
Dried.....	4§									
Min.....		11.13	3.13	.....	0.67	25.87	2.46	.....	2.30	1.94
Max.....		22.43	5.63	.....	1.31	55.03	34.49	.....	3.60	2.92
Aver....		**16.24**	**4.42**	.....	**1.15**	**39.24**	**20.78**	.....	**3.17**	**2.32**

* Weight of fruit 6 to 18 grams; pulp in fruit 91 to 96%. † 2 samples. ‡ 4 samples. § Weight of fruit 3 to 8 grams; pulp in fruit 85 to 89%.

The seeds of the jujube, as analyzed by Sherman and Wang,[3] contained: water 21.32, protein 2.28, fat 0.36, nitrogen-free extract 72.56, fiber 2.22, and ash 1.26 per cent.

Mineral Constituents.—Percentages of ash in the seed-free pulp 2 varieties, and analyses of ash by Benoy,[4] are here given. The alkalinity of the ash is shown by the marked preponderance of constituents.

S. Dept. Agr., Off Exp. Sta. 1899, Bul. **68**.

S. Dept. Agr. 1924, Bul. **1215**, p. 24.

lippine J. Sci. 1929, **38**, 69.

gr. Res. 1929, **39**, 949.

Composition of Ash of Jujube Pulp (Benoy)

	Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	MnO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%	%
I.	1.03	56.40	1.65	5.42	4.46	0.12	1.11	1.04	1.85	0.28	4.08
II.	1.42	54.78	1.29	5.60	3.53	0.12	0.99	0.64	1.40	0.27	3.49

FRUITS OF THE GRAPE FAMILY

(*Vitaceæ*)

THE grapes all belong to the genus *Vitis*. So far as noted, European and American grapes differ little in structure, excepting the thicker outer wall of the epicarp of the American species.

AMERICAN GRAPE

Vitis Labrusca L., *V. æstivalis* Michx., *V. rotundifolia* Michx., etc.

Although the number of species of grape indigenous to North America is larger than in any other region, the fruit of all taken together does not equal in importance that of the single European species *V. vinifera*. Nevertheless numerous varieties have been developed from native species which in the Eastern States furnish table fruit through a limited season and unfermented juice for bottling. Grafting scions of European varieties on the stocks of American species has proved to be the best method of combating *Phylloxera*.

The northern fox grape (*V. Labrusca*) is the parent of the famous Concord (black), the Catawba (red), and other common varieties. The Niagara (white) and the Brighton (red) are hybrids of *V. Labrusca* and *V. vinifera*. Other *Labrusca* hybrids are designated as to their origin in a subsequent table under Odorous Constituents. The Summer grape (*V. æstivalis*), regarded by some as a variety of *V. Labrusca*, is the parent of certain wine varieties, and the Muscadine or southern fox grape (*V. rotundifolia*) of the Scuppernong, also a well-known wine variety.

Of all American varieties, the Concord is the most extensively grown both on a large scale and in the home garden, the fruit being used for dessert and the production of sterilized bottled grape juice. It is not, however, well suited for wine making, nor do any of the rictly American varieties yield a wine meeting the demands of the cure. As a dessert fruit, American grapes are remarkable for the ety and delicacy of their flavors, although the tough skin, which jected in eating, the tough fruit flesh, and the high acidity of the pulp make them less attractive to most consumers than fruit of European species.

Raisins are not made from American grapes, partly because the fruit is not suitable and partly because the climate does not permit sun drying. On the other hand, excellent jam and preserves are made from them, although strange to say the wild fruit, which because of the excessively thick rind and tough fruit flesh is not relished uncooked, is preferred to the cultivated fruit for this purpose.

MACROSCOPIC STRUCTURE.—All the species are polygamo-diœcious. The numerous fragrant but inconspicuous greenish yellow *flowers* have a minute calyx, five petals united at the tip and separating only at the base, five stamens alternating with as many glands on a disk, and a two-loculed ovary each locule normally with two anatropous ovules.

The *fruit* is a black, red, or yellow-green berry, often with a bloom. The number in a bunch varies greatly. On removing the stem, usually the disk and a portion of the central fruit tissues, consisting of fibro-vascular bundles and some soft tissues, are carried with it. When fully ripe the translucent, whitish green or pink, delicately veined pulp may be removed from the rind by pinching with the thumb and first finger, this being the common practice in eating. The normal number of seeds (four) is seldom present.

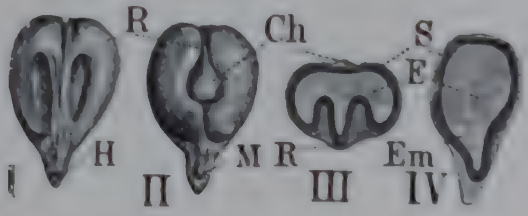

Fig. 256.

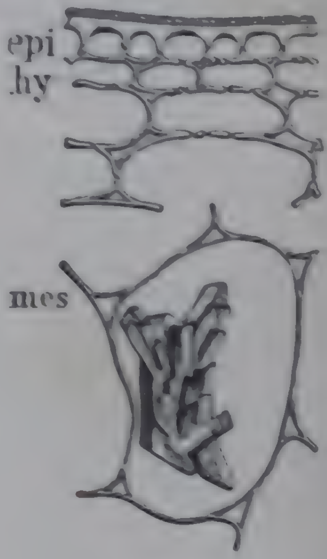

Fig. 257.

Fig. 256.—American Grape. Seed. I ventral side, II dorsal side, III cross section, IV longitudinal section. *H* hilum; *M* micropyle; *Ch* chalaza; *R* raphe; *S* spermoderm; *E* endosperm; *Em* embryo. × 2. (K.B.W.)

Fig. 257.—American Grape. Outer pericarp in cross section. *epi* epicarp with cuticle; *hy* hypoderm; *mes* mesocarp with sugar crystals as formed in alcoholic specimen. × 160. (K.B.W.)

The *seeds* (Fig. 256) are pear-shaped, on the ventral side (I) with two longitudinal grooves between which is the raphe (*R*) and on th dorsal side (II) the chalaza (*Ch*) also near the base, the micropy (*M*). A cross section (III) shows that the inner hard tissues of spermoderm (*S*) are more deeply grooved than the outer, also that endosperm (*E*) is horny. So minute is the embryo (IV, *Em*), loc near the smaller end, that it is visible only after careful study of lo tudinal sections. It is best brought out by soaking the seed for several days in water or better very dilute sodium hydroxide, after which it separates entire.

MICROSCOPIC STRUCTURE.—Hanausek[1] describes briefly without illustrations the structure of the pericarp of the European grape. Later Hanausek,[2] Vogl, Villier and Collin, and other authors of treatises give data for the detection of grape seeds as an adulterant of coffee. Howard[3] notes the character of certain pulp tissues including the bundles.

The description and illustrations which follow are of the Concord grape to which all other American grapes we have studied conform in structure. A comparison of the histology of the American and the European grapes is given under the latter.

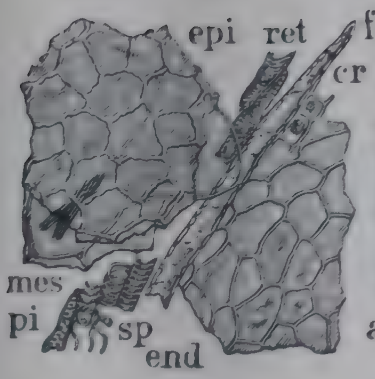

Fig. 258.

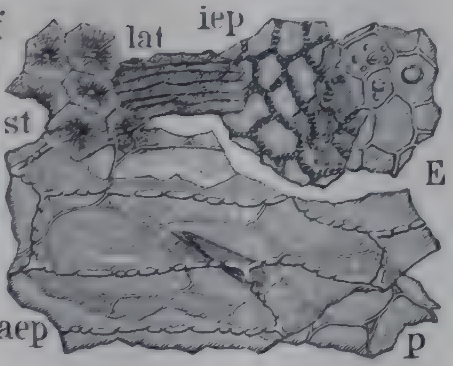

Fig. 259.

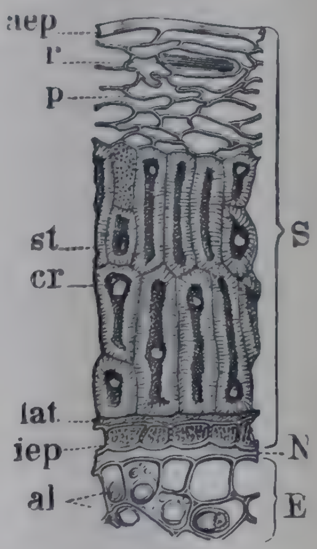

Fig. 260.

Fig. 258.—American Grape. Elements of pericarp in surface view. *epi* epicarp; *mes* mesocarp with raphides; *f* bast fiber; *cr* crystal fiber; *sp* spiral, *ret* reticulated, and *pi* pitted vessels; *end* endocarp. × 160. (K.B.W.)

Fig. 259.—American Grape. Elements of seed in surface view. Significance of reference letters as in Fig. 260. × 160. (K.B.W.)

Fig. 260.—American Grape. Seed in cross section. *S* spermoderm: *aep* outer epiderm, *p* parenchyma with *r* raphides, *st* stone cell layer with *cr* crystals, *lat* lattice cells, *iep* inner epiderm. *N* perisperm. *E* endosperm with *al* aleurone grains. × 160. (K.B.W.)

Pericarp (Figs. 257 and 258).—The tissues are in four layers passing one into the next, namely (1) *epicarp* (*epi*) of polygonal cells, with thick outer walls and porous radial and inner walls; (2) *hypoderm* (*hy*) polygonal cells, with porous walls, increasing in size inward and passing into (3) *mesocarp* (*mes*) of large, thin-walled, rounded cells (showing sugar crystals in alcohol material), occasional raphides cells, and numerous fibro-vascular bundles with spiral (*sp*), pitted (*pi*), and reticulated (*ret*) vessels, crystal fibers (*cr*), and long bast fibers (*f*); and (4) *endocarp* (*end*) of polygonal cells.

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[1] Nahr.-Genussm. Kassel, 1884, p. 182.

[2] Dammer: Lex. Verfäls. Leipzig, 1885, **1**, 389.

[3] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **66**, 103.

In black and red varieties the coloring matter is dissolved in the sap of the *epicarp* and *hypoderm*. These tissues also give the tannin reaction with ferric chloride solution.

The *spiral vessels* often have double thickenings. In the smaller bundles all the vessels are spiral. Bast fibers are more numerous in European grapes of the Tokay type, as noted in the following section.

Alwood[1] notes the presence of minute cream of tartar crystals in the outer mesocarp cells but not in the inner main pulp tissues or those immediately surrounding the seed. Chemical analysis confirmed these observations.

Spermoderm (Fig. 259; Fig. 260, *S*).—There are five well-marked layers: (1) *outer epiderm* (*aep*) of large, transversely elongated, cuticularized, porous cells; (2) *parenchyma* (*p*), some of the cells containing raphides; (3) *stone cells* (*st*), usually two deep, characterized by their brown color, radial elongation, and the presence of a single oxalate crystal in an amorphous mass; (4) *lattice cells* (*lat*) characterized by their brown color, narrow width, transverse elongation, and delicate markings; and (5) *inner epiderm* (*iep*) of light brown, nearly isodiametric, porous cells.

The *parenchyma* forms a thin layer, except in the grooves where it is much thicker. In the grooves, on the other hand, the stone cell layer is thinner, often only one cell thick. The *lattice cells* show well their details of structure after bleaching with Labarraque solution and staining with safranin.

Perisperm (Fig. 260, *N*).—This is reduced to a structureless band seen in cross section.

Endosperm (Figs. 259 and 260, *E*).—The bulk of the seed consists of the rather thin-walled aleurone cells of the endosperm. These are remarkable for the aleurone grains (up to 25 μ) which, mounted in turpentine, show well-developed crystalloids, calcium oxalate rosettes, and large globoids. Some contain only one of these bodies, others two different kinds such as a crystalloid and a rosette, or a globoid and rosette, or a crystalloid and one or more globoids.

Chief Structural Characters.—Berry round, smooth, black, red, or yellow-green, two-loculed, four-seeded or less. Seed p shaped with two grooves; endosperm horny; embryo minute.

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[1] J. Agr. Res. 1914, 1, 513.

Mesocarp with raphides cells; fibro-vascular bundles with spiral, reticulated, and pitted vessels, also occasional bast and crystal fibers. Spermoderm with raphides cells, radially elongated stone cells, lattice cells, and porous-walled inner epiderm. Endosperm with aleurone grains (25 μ) containing crystalloids, globoids, and oxalate rosettes.

CHEMICAL COMPOSITION.—The average of 5 analyses of the edible portion given in Atwater and Bryant's Compilation,[1] showing water 77.4, protein 1.3, fat 1.6, total carbohydrates including fiber 19.2, and ash 0.5 per cent, leaves one uncertain as to whether the fruit is of the American or European type and throws no light on the content of sugar and acid.

Analyses of 49 American varieties reported by Green [2] showed 8.8 to 16.6 per cent of total sugars calculated as dextrose in the whole grape and 1.0 to 2.0 per cent of acids calculated as tartaric in the juice.

American Grape Juice.—Passing over analyses of commercial grape juice of uncertain origin, the composition of this popular bottled beverage is well illustrated by analyses reported by Gore and by Hartmann and Tolman—all government analysts—the product having been prepared on a commercial scale but under supervision.

The juice of varieties derived from *V. rotundifolia* (Scuppernong, Mish, and James) and of two of the commonest varieties derived from *V. Labrusca* (Concord and Catawba), as analyzed by Gore,[3] contained as shown below. The juices of the *rotundifolia* varieties were deficient in total sugars but contained appreciable amounts of sucrose as discussed in a subsequent section.

COMPOSITION OF AMERICAN GRAPE JUICE (GORE)

	Samples	Solids	Protein	Acids as tartaric	Tartrates*	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.†	P_2O_5
		%	%	%	%	%	%	%	%	cc	%
Scuppernong.	1	14.77	0.07	0.72	0.45	13.42	0.07	0.026	0.16	16	0.015
Mish........	1	16.57	0.14	0.81	0.53	12.88	1.90	0.027	0.22	23	0.014
James.......	1	13.47	0.07	0.44	0.30	12.33	0.00	0.035	0.19	17	0.012
Concord:	6										
Min.......		19.27	0.27	0.68	0.56	17.04	0.00	0.06	0.27	27	0.026
Max......		22.17	0.45	1.02	0.71	18.95	0.00	0.44	0.32	32	0.048
awba....	1	20.07	0.42	0.93	0.67	17.98	0.00	0.06	0.27	24	0.026

* As tartaric acid. † Cc. *N*/10 acid per 100 cc. juice.

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[1] U. S . S. Dept. Agr., Off. Exp. Sta. 1906, Bul. 28 rev.

[2] J. A innesota Agr. Exp. Sta. 1892, Bul. 25, 237.

[3] Farn . Ind. Eng. Chem. 1909, 1, 436.

During three years a study of the manufacture of bottled Concord grape juice at six factories, one in the Hudson River district, four in the Chautauqua (New York) district, and one in the Lake Erie (Ohio) district, was carried out by Hartmann and Tolman.[1] The process employed was in six stages (1) crushing and stemming, (2) heating, (3) pressing, (4) sterilizing and bottling, (5) siphoning, and (6) rebottling and pasteurizing. Among the special points investigated were the influence of heating the crushed fruit at 57° to 65° C. prior to pressing, which is the usual process, the influence of different degrees of pressure, and the changes during storage, data on all of which, together with the composition of 104 juices, are summarized below:

COMPOSITION OF CONCORD GRAPE JUICE (HARTMANN AND TOLMAN)

(Grams per 100 cc.)

	Solids	Invert sugar	Alcohol	Acids as tartaric	Tartaric acid, total	Tartaric acid, free	Cream of tartar	Tannin and color	Ash, total	Ash, Alk.*
Cold Pressed:										
Min.	15.66	13.38	.....	0.74	0.55	0.09	0.42	0.06	0.20	25
Max.	17.20	14.36	.....	0.84	0.65	0.24	0.62	0.08	0.27	37
Aver.	**16.36**	**13.93**	.....	**0.78**	**0.61**	**0.16**	**0.50**	**0.07**	**0.23**	**30**
Hot pressed:										
Min.	16.44	13.29	.....	1.01	0.94	0.12	0.71	0.19	0.33	42
Max.	18.50	15.12	.....	1.16	1.04	0.33	1.05	0.24	0.46	61
Aver.	**17.43**	**14.03**	.....	**1.09**	**0.99**	**0.22**	**0.88**	**0.21**	**0.39**	**51**
Free run	16.70	13.42	.....	1.08	0.99	.....	....	0.27	0.41	..
High pressure	17.10	13.48	.....	1.27	1.11	.....	....	0.31	.....	..
Fresh:										
Min.	16.99	13.25	.....	0.98	0.85	0.13	0.64	0.15	0.34	40
Max.	19.76	16.39	.....	1.27	1.03	0.31	0.86	0.28	0.44	54
Aver.	**17.92**	**14.54**	.....	**1.14**	**0.94**	**0.21**	**0.77**	**0.22**	**0.39**	**49**
Stored 4 months:										
Min.	16.41	13.34	.....	0.83	0.58	0.13	0.47	0.13	0.22	28
Max.	19.18	16.15	.....	1.10	0.84	0.28	0.63	0.22	0.32	38
Aver.	**17.39**	**14.52**	.....	**1.01**	**0.70**	**0.22**	**0.53**	**0.18**	**0.27**	**32**
6 Factories, 3 yrs.:										
Min.	14.20	11.52	0.02	0.81	0.56	0.12	0.36	0.07	0.22	
Max.	20.78	17.53	0.37	1.28	1.01	0.36	0.79	0.37	0.37	
Aver.	**18.33**	**15.31**	**0.12**	**1.01**	**0.74**	**0.23**	**0.54**	**0.24**	**0.29**	

* Cc. $N/10$ acid per 100 cc. juice.

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[1] U. S. Dept. Agr., 1918, Bul. **656**.

Changes in Composition during Ripening.—Alwood, Hartmann, Eoff, Ingle, and Sherwood[1] conducted experiments at Sandusky, Ohio, and Charlottesville, Virginia, with the following varieties: Catawba, Clinton, Concord, Delaware, Ives, Norton, and Cynthiana. Although analyses were made at intervals of 3 to 4 days to over a week, the general character of the changes is well illustrated by the results on the fruit and juice of one variety, Catawba, obtained at the beginning of the experiment and after full ripeness was reached.

COMPOSITION OF CATAWBA GRAPES AND GRAPE JUICE BEFORE AND AFTER RIPENING (ALWOOD ET AL.)

	Solids	Sugar as invert	Total acids as tartaric	Tartaric acid, total	Tartaric acid, free	Other fixed acids	Cream of tartar	Alkali-earth tartrates	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	cc.
Fruit:										
Sept. 4	......	3.29	3.15	0.90	0.40	2.50	0.46	0.15	0.38	36
Oct. 23	......	13.26	1.27	0.75	0.07	0.86	0.72	0.11	0.47	41
Juice:										
Sept. 4†	8.24	3.48	3.56	1.16	0.76	2.60	0.38	0.10	0.23	27
Oct. 23‡	17.34	14.01	1.19	0.60	0.07	0.85	0.55	0.09	0.31	36

* Cc. $N/10$ acid per 100 grams of substance. † Weight of 100 berries 166 grams. ‡ Weight of 100 berries 214 grams.

Noyes, King, and Martsolf,[2] in studies on the Concord grape, state that after ripening reaches a certain point changes in sugar are irregular. Tannin and coloring matter are much higher in hot- than in cold-pressed juice.

Influence of Season on Composition of Grape Juice.—Analyses of the juice of 49 varieties of American grapes, grown at Vineland, New Jersey, which fruited during each of 5 years and of 16 others which fruited irregularly during that period were made by Caldwell.[3] Among the points brought out is the widespread but erratic occurrence of sucrose n grapes, indicative in some degree of immaturity. It is noted that nditions permitting a maximum accumulation of sugars also tend to ce the titratable acidity and astringency. The author concludes the variation encountered in fruit of a given variety when grown in one locality is much less than when grown in different sections. The extremes in composition of a few of the common varieties and of all varieties and samples during the five years appear in the table which follows:

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[1] U. S id., 1916, Bul. 335.

[2] J. A Ass. Off. Agr. Chem. 1922, 6, 197.

[3] Far Agr. Res. 1925, 30, 1133.

VARIATIONS IN COMPOSITION OF THE JUICE OF AMERICAN GRAPES GROWN IN ONE LOCALITY FOR 4 TO 5 YEARS (CALDWELL)

	Years	Solids	Acids as tartaric	Sugars, total	Invert sugar	Sucrose	Astringency, total*	Tannin*	Astringency, non-tannin*
	%	%	%	%	%	%	g.	g.	g.
Brighton:	5								
Min.		23.66†	0.57	16.96	16.96	0.00	1.05‡	0.43‡	0.60‡
Max.		24.16†	0.76	23.08	23.08	0.54	1.66‡	0.73‡	0.96‡
Catawba:	5								
Min.		19.94†	0.82	16.64	15.60	0.00	1.16‡	0.26‡	0.77‡
Max.		21.64†	1.23	20.66	20.66	1.91	1.54‡	0.55‡	0.98‡
Clinton:	5								
Min.		21.46†	1.53	17.02	16.40	0.00	1.11‡	0.08‡	1.04‡
Max.		21.78†	1.76	22.44	22.44	1.30	1.75‡	0.54‡	1.31‡
Concord:	5								
Min.		16.52†	0.77	13.44	13.23	0.00	0.94‡	0.40‡	0.50‡
Max.		16.97†	1.18	15.20	15.02	0.52	1.87‡	0.87‡	1.00‡
Delaware:	4								
Min.		21.21†	0.70	17.21	16.82	0.00	0.68†	0.15†	0.53†
Max.		26.08†	0.84	25.25	24.80	0.45	0.73†	0.18†	0.55†
Isabella:	5								
Min.		18.23†	0.78	16.35	12.25	0.00	0.93‡	0.24‡	0.57‡
Max.		18.84†	1.33	18.53	17.56	4.10	0.95‡	0.36‡	0.71‡
Ives:	4								
Min.		16.24†	0.55	12.96	11.74	0.04‡	1.01†	0.14†	0.87†
Max.		17.58†	1.42	16.39	15.67	2.80‡	1.86†	0.61†	1.25†
Niagara:	5								
Min.		17.50‡	0.61	14.58	14.25	0.00	0.78‡	0.13‡	0.65‡
Max.		18.83†	0.75	17.00	17.00	0.56	1.27‡	0.19‡	1.13‡
Worden:	5								
Min.		13.94†	0.58	11.41	9.75	0.00	0.95‡	0.22‡	0.73‡
Max.		16.34†	1.07	15.60	14.79	5.57	1.67‡	0.61‡	1.05‡
All varieties:§.									
Min.		12.92	0.53	9.37	8.80	0.00	0.22	0.03	0.38
Max.		26.08	2.10	25.25	24.80	5.57	4.01	2.35	1.9

* Grams per liter. † Two years. ‡ Three years. § 290 samples.

Fatty Oil of Seed. *Physical and Chemical Values.*—Beal and B

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[1] J. Ind. Eng. Chem. 1915, 7, 1054.

by extraction of seeds of *V. riparia* with petroleum ether, secured a yield of 19.38 per cent of oil with values as follows: specific gravity at 15° C. 0.9425; refractive index at 25° C. (recalculated) 1.4745; saponification number 187.8; iodine number 76.5; acetyl number 61.3; insoluble fatty acids 90 per cent, with neutralization value 173.4; liquid acids 95 per cent and solid acids 5 per cent of total fatty acids; iodine number of liquid acids 91.8, of solid acids 3.12; mean molecular weight of solid acids 268.6.

By decortication and pressure, Rabak[1] secured from seed of the Concord grape 14.5 per cent of oil which on refining yielded volatile acids 0.47, insoluble acids 94.75, solid acids 7.17, and liquid acids 85.41 per cent. The mean molecular weights of the insoluble, solid, and liquid acids were 287.8, 264.5, and 290.8 respectively. Physical and chemical values of the oil are given in the following table:

VALUES OF CONCORD GRAPE SEED OIL (RABAK)

	Sp. gr. 15° C.*	Ref. index 25° C.	Solid. point† ° C.	Sapon. No.	Iodine No.	Acid No.
Crude oil.	0.9272	1.4720	−20	193.4	134.1	1.21
Refined oil.	0.9268	1.4720	−23	192.2	135.8	0.74
Insoluble acids.	0.9111	1.4637	+9.5	. . . . .	137.0	194.9§
Solid acids.	. . . . . .	. . . . . .	+54‡	. . . . .	. . . . .	212.1§
Liquid acids.	0.9144	1.4652	−8.2	. . . . .	144.7	192.9§

* Recalculated. † Average. ‡ Melting point. § Neutralization value.

Mikshich and Rezhek[2] found that the oil from seeds of the variety Noah, a hybrid of the American species *V. riparia* and *V. labrusca*, grown in Yugoslavia, showed: specific gravity (temp. ?) 0.9221; iodine number 135.1.

Composition.—From their neutralization value and their calculated molecular weight, the solid acids found by Beal and Beebe[3] were alculated to consist of palmitic acid 64.3 and stearic acid 35.7 cent. By fractional crystallization of the brominated liquid , were obtained linoleic acid 56 and oleic and ricinoleic acid r cent.

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[1] U. S d. 1921, 13, 919.

[2] J. Ar . soc. chim. roy. Yougoslav. 1930, 1, 29, 32.

[3] Farn . cit.

Calculation of the composition of the oil examined by Rabak gave:

	%
Stearin	2.3
Palmitin	5.2
Olein	35.9
Linolein	53.6
Unsapon. matter	1.6
	98.6

Mikshich and Rezhek[2] found erucic acid in the oil from the seed of the Noah variety. Täufel and Thaler[3] doubt the presence of eruci acid. They were unable to find any acid with a molecular weight greate than that of stearic acid.

Acids.—Nelson,[4] by the ester distillation method, identified *l-mali acid* (about 60 per cent) and *d-tartaric acid* (about 40 per cent) in th Concord grape. In this variety, Hartmann and Hillig,[5] by the pentabromoacetone method, were able to find a small amount of *citric acid*.

Alwood,[6] in corroboration of microscopic observations, found tha while the juice expressed from the hulls is very low in tartaric acid, th residue, although less than half as acid as the pulp, is nearly as rich i free tartaric acid and cream of tartar as the inner pulp.

The combinations in which the tartaric acid exists and the aci content at different stages of maturity are considered under Change in Composition During Ripening.

Carbohydrates.—Various continental authors have stated positivel that the sugars of the European grape (*V. vinifera*) consist entirely o invert sugar and that sucrose is absent. Studies by Roos and Hugues of American varieties grown in France led to the same conclusion Gore, however, in 1908[8] secured distinct evidence that *sucrose* is presen in appreciable amount in grapes of the *rotundifolia* group, and some year later[9] he extended the search to 66 American varieties and throug four successive seasons. He found that 43 varieties contained n sucrose, 10 contained it occasionally, and 13 contained it frequently To the last-named class belong Campbell's Early, Colerain, Earl

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[1] J. Ind. Eng. Chem. 1921, **13**, 919.

[2] Loc. cit.

[3] Fettchem. Umschau 1934, **41**, 196.

[4] J. Am. Chem. Soc. 1925, **47**, 1177.

[5] J. Ass. Off. Agr. Chem. 1928, **11**, 257.

[6] Loc. cit.

[7] Ann. fals. 1910, **3**, 202.

[8] Loc. cit.

[9] J. Ind. Eng. Chem. 1916, **8**, 333.

ctor, Eden, Lady, Moore's Early, Nectar, Pocklington, Scuppernong, homas, Woodruff, and Herbert.

Alwood,[1] also Alwood and Eoff,[2] found as high as 10.36 per cent of crose in the immature berries of a seedling, apparently of the *Labrusca* oup, and over 7 per cent at full maturity. The table above, showing aldwell's analyses, adds further evidence on the occurrence of sucrose American grapes, also, as that author notes, on the irregularity of s occurrence and its usual but not invariable correlation with immarity.

Pectins.—Willaman and Kertesz[3] remove the turbidity of grape ice by an enzyme produced by *Penicillium glaucum* which converts ost of the pectin into soluble substances and precipitates a portion gether with other suspended matter. About two-thirds of the pectin removed, according to Green and Kertesz.[4] During storage both ectin and tartaric acid decrease.

The pectin extracted by Barbera[5] from European grapes by boiling ielded arabinose, xylose, methanol, galacturonic acid, and galactose. contained more ash and less methoxyl than pectin from oranges and osaceous berries.

Colors.—Anderson,[6] in the varieties Norton and Concord, and nderson and Nabenhauer,[7] in the variety Clinton, probably a derivave of *V. riparia* and *V. Labrusca*, found a pigment differing from the nin of the European grape and its hybrids in that it contained only ne methyl group. It was shown to be the monoglucoside of the *monoethyl ester of delphinidin.* Other anthocyanins are possibly present. nderson as noted in his Bulletin showed that the anthocyanin in the ariety Seibel, a hybrid derived from *V. vinifera,* is enin inherited rom its European ancestor.

Parisi and Bruini[8] prepared from the variety Fogarina an anthoyanin and anthocyanidin, having the same reactions as those from he American species *V. riparia,* which they regard as proof that the ariety is an American-European hybrid.

Odorous Constituents.—*Methyl anthranilate,* the methyl ester of -amidobenzoic acid, $C_6H_4(NH_2)(COOCH_3)$, the chief odorous constiuent of orange flowers, and one of several of jasmine, gardenia, and tuberose flowers, bergamot leaves, and sweet orange rind, in dilute solution, has an odor closely resembling that of Concord grape juice.

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[1] Ibid. 1910, **2**, 481.

Ibid. 1916, **8**, 334.

ew York State Agr. Exp. Sta. 1931, Tech. Bul. **178**, 3.

id. 1931, Tech. Bul. **181**.

n. tec. agr. 1933, **6**, No. 3, I, 229, 350.

Biol. Chem. 1923, **57**, 795.

. 1924, **61**, 97; New York Agr. Exp. Sta. 1928, Tech. Bul. **146**.

sper. agr. ital. 1926, **59**, 130.

Power,[1] employing principles previously used in an analytical method devised by Erdmann,[2] developed a process which in the hands of Power and Chesnut[3] showed amounts of the ester varying up to 2 mg. per liter in red grape juice of the Concord type and up to 0.2 mg. per liter in light-colored juices. In few cases were absolutely negative results obtained.

Sale and Wilson[4] found that, out of 55 varieties of American grapes, only 15—and not in all cases in some of these—contained anthranilic acid ester (calculated as methyl anthranilate), none of these being of the pure *vinifera* type, although several were derived in part from that species. Although the percentage was highest in the skins, appreciable amounts occurred in the pulp. Determinations were also made of the volatile esters and volatile acids. Selected results are tabulated below, the parent species being indicated by the following symbols: L, *Vitis*

FLAVORING MATTER OF AMERICAN GRAPES (SALE AND WILSON)

	Anthranilic acid ester*	Volatile esters†	Volatile acids‡	Anthranilic acid ester in vol. esters†
	mg. per k.	mg. per k.	mg. per k.	%
Fruit:				
Campbell (LV)	0.00	360	70	0.0
Diana (LVA)	0.00	48	48	0.0
Clinton (RL)	0.00	8	7	0.0
Brighton (LV)	0.12	64	71	0.1
Cloeta (LiRuLV)	0.00	20	48	0.0
Delaware (LBV)	0.36	....	....	....
Concord (L)				
Min.	0.91	57	9	1.2
Max.	3.80	170	50	1.4
All varieties:				
Min.	0.00§	6‖	3‖	0.0§
Max.	3.80§	366‖	121‖	8.8§
Skin and Pulp:				
Skin juice	4.40	128	53	2.0
Pressed skin	19.50	127	58	9.0
Drained pulp	3.00	154	49	1.1

* As methyl anthranilate. † As ethyl acetate. ‡ As acetic acid. § 55 varieties, 84 samples. ‖ 34 varieties, 50 samples.

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[1] J. Am. Chem. Soc. 1921, **43**, 377.

[2] Ber. 1902, **35**, 24.

[3] J. Am. Chem. Soc. 1921, **43**, 1741.

[4] J. Agr. Res. 1926, **33**, 301.

Labrusca; B, *V. bourquiniana*; V, *V. vinifera*; R, *V. riparia*; A, *V. æstivalis*; Li, *V. lincecumli*; and Ru, *V. rupestris*.

The same authors found that the anthranilic acid ester slowly disappeared during storage of the juice. A sample of commercial juice, containing 1.35, fortified so as to contain 6.56 mg. per liter, after storage 10 months contained only 4.05 and after 8 additional months only 0.70 mg. per liter.

Scott[1] reports in Concord grape juice 0.80 to 1.49, in Catawba grape juice 0.11 to 0.40, and in artificially flavored carbonated beverages 7.1 to 17.5 mg. per liter of methyl anthranilate. Artificial extracts contained 0.27 to 0.51 gram per 100 cc.

Mineral Constituents.—Analyses by Eoff as reported by Alwood et al.[2] show the mineral constituents of Catawba and Concord grapes on September 24. The Catawba berries were 60 per cent pink, the Concord berries nearly ripe. Since the increase in ash thereafter is slight, it may be assumed that the analyses given below represent fairly well the ripe fruit:

	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	Cl
	%	%	%	%	%	%	%
Catawba......	0.392	0.177	0.002	0.044	0.026	0.051	0.002
Concord.......	0.445	0.217	0.004	0.030	0.021	0.044	0.001

Minor Mineral Constituents. *Iron.*—Red grapes 9, Concord skin 13.6, Concord pulp 7.4 mg. per kilo, fresh basis (Peterson and Elvehjem).[3]

Copper.—Black grapes 8.1 mg. per kilo (Satterfield and Jones)[4]. Grape juice 0.2 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson.[5]

EUROPEAN GRAPE

Vitis vinifera L.

Fr. Raisin. Sp. Uva. It. Uva. Ger. Traube.

Kolenati (quoted by De Candolle) groups the wild vines growing between the Caspian and Black Seas—a region believed to be the original home of the species—under two sub-species. Regel's more recent view that the cultivated species is a hybrid of two species appears to lack confirmation.

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[1] Ind. Eng. Chem. 1923, **15**, 732.

[2] U. S. Dept. Agr. 1916, Bull. **335**.

[3] J. Biol. Chem. 1928, **78**, 215.

[4] J. Elisha Mitchell Sci. Soc. 1932, **48**, 16.

[5] J. Biol. Chem. 1929, **82**, 465.

Grapes of the European type are grown and varieties are developed with three ends in view: (1) wine production, (2) table fruit, and (3) raisin production. The wine and table grape regions extend from the sub-tropical borders of the Mediterranean into the more temperate parts of Europe and cover parts of Australia and California. The varieties grown both out-of-doors and under glass are numerous and of varied character. In California the Zinfandel grape leads as a wine grape. Among the table varieties grown there are the Tokay (red), Malaga (white), Emperor (red), and Cornichon (black), all well known in American markets. Recently the delicious small white seedless grape, such as is used for Sultana raisins, has been shipped in large quantities.

Raisins demand for their drying a hot arid climate such as is found in Spain, Asia Minor, Greece, and neighboring regions, as well as in parts of Australia and California. According to Bioletti, the large-seeded California raisin (from which the seeds are removed before packing) is commonly the dried Muscat of Alexandria grape, whereas the commercial seedless raisin is the dried Sultanina (Thompson Seedless or Oval Kechmish) or Sultana (Round Kechmish) grape. In Europe certain types of raisins are dried on the vine after bruising the stem to cut off the supply of sap and removal of the leaves. In California, Muscatel raisins are dried on trays in the sun. In Europe, Valencia raisins and in California Sultana raisins are dipped in lye, then in water to remove the excess of lye, and sulphured before sun drying. By this treatment a light-colored raisin is obtained and the bloom is removed, but if oil is used in the dipping bath an artificial bloom is produced.

Uflerbaumer[1] states that cold-pressed oil (wine oil) from the seeds is much used by South German peasants in cooking. The cake is said to furnish good food for sheep.

Xanti currants are small-fruited grapes (*V. vinifera* var. *apyrena*) grown and sun dried in Greece.

MACROSCOPIC STRUCTURE.—Classification of the species of the genus *Vitis* is based largely on characters of the leaf, bark, and in a lesser degree on the size, color, and minor characters of the berry. Neither flowers nor berries show any marked structural differences.

Whereas American grapes are round, most European varieties, as for example Tokay, Malaga, and especially Cornichon, are more or less elongated. There are, however, round-berried European varieties, such as Black Prince and other black and red varieties with large berries, grown under glass. As regards the number and size of the seeds, varieties differ, the number ranging from the normal of four to none in the seedless varieties.

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[1] Chem. Umschau 1916, **23**, 20.

The tender edible rind, the firm but tender pulp, and the lack of a tendency of the rind to separate from the pulp on pinching are characters distinguishing the European type from varieties derived from American species.

MICROSCOPIC STRUCTURE (see references under American Grape).—Examination of numerous varieties of both the European and the American type has failed to disclose any fundamental difference between the two. Variation in the size of the cells has been noted in different varieties but the range of this variation cannot be said to be materially different in one from that in the other. For example, in a specimen of Concord grape the maximum tangential diameter of the epicarp cells was 40 μ, while in a specimen of Tokay grape it was 80 μ, of Muscatel raisin 30 μ, and seedless raisin 30 μ. In general it appears to be true that the size of the cells is greater in varieties with large berries than in those with small berries.

The toughness of the rind of American grapes is largely due to the thickness of the outer wall of the epicarp, although this varies greatly in different varieties and different specimens of the same variety. Bonnet,[1] in a comparison of American with a large number of varieties of European grapes, obtained the following measurements: *V. æstivalis* 8.3, *V. arizonica* 5.7, *V. berlandieri* 8.5, *V. cinerea* 8, *V. coriacea* 9.9, *V. labrusca* 7.6, *V. monticola* 6.7, *V. riparia* 6.5, *V. rubra* 7.8, *V. rupestris* 4.6, and *V. Vinifera* 3.8 μ, all but the last named being American species. These figures are consistent with the following measurements made by the writers through the center of the outer walls: Concord, two specimens from different sources, 7 and 8.1 μ; Tokay, two berries from same bunch, 3 and 5.4 μ; Muscat raisin 4 μ; seedless raisin 2.7 μ. Although these figures furnish histological evidence with regard to the toughness of the rind, the difference in the toughness of the pulp of the American and European grape is not explained. In both, the walls are thin, but in the European grape the fibro-vascular bundles instead of being weaker may be tougher, as for example in the Tokay variety, owing to a greater proportion of bast fibers.

The reason why the rind of the American grape is readily pinched off from the pulp while that of the European grape remains firmly attached is also not apparent, although in the banana and mamey the reason for the separation is readily found on examining cross sections.

Hanausek in his cut shows stronger radial development of the stone cells of the spermoderm in the Malaga grape than in the Zinfandel. In a specimen of Malaga grape examined by us, however, the stone cell layer was like that found in the Concord grape and by Hanausek in the other variety he examined. It would thus appear that the development of this layer, as of others of the pericarp and seed, is not a constant character of a variety and much less of the type.

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[1] Ann. École Nat. Agr. Montpellier 1903, **3**, 58.

De Villiers[1] found reducing sugars throughout the fruit except around the primary and secondary vascular strands. In the ripe fruit tannin was confined to the vicinity of the vascular tissues and the subepidermal layers. Enin, the coloring principle, was in solution in the epicarp cells.

CHEMICAL COMPOSITION.—Data on the composition of the wine and must (juice) or even on the seed and marc are much more voluminous and complete than on the pulp or edible portion excluding the seeds which, when swallowed whole with the pulp, go through the body undigested. The only analyses of the pulp available are either antiquated or incomplete.

European Grape Juice.—The composition of European grape juice or must of different regions and years is brought out by numerous analyses (taken from "Deutsche Weinstatistik") covering fourteen pages of König's Compilation[2] to which the reader concerned with this intermediate product of wine manufacture is referred. Notwithstanding its bulk, König states that his compilation is far from exhaustive.

The averages of 6, 9, and 6 samples of the juice of European varieties grown in California, reported by Colby in Reports of the California Experiment Station during the years 1887 to 1893, showed respectively: total sugars 21.05, 23.47, and 21.68; reducing sugars 21.05, 23.14, and 19.82; acidity as tartaric 0.646, 0.358, and 0.606; and ash 0.21, 0.37, and 0.23 per cent. These analyses may be taken as fairly representative of the must as analyzed abroad which only in exceptional cases contained over 25 per cent of total sugars or 1.25 per cent of acids or less than 12 per cent of total sugars or 0.5 per cent of acids. Instances where the total sugars reached 35 per cent, because of drying of the grapes, or fell to 0.5 per cent, from various causes, call for special comment.

Composition of Grape Seeds, Marc, and Cake.—The following results by Margaillan and Rabelle[3] on the seed, by Sémichon[4] and

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[1] Union S. Africa Sci. Bul. 1926, **45**, 6.

[2] Chem. mensch. Nahr.-Genussm., Berlin, 1903, **1**, 1160.

[3] Ann. off. nat. comb. liq. 1927, **2**, 825.

[4] Soc. aliment. rationn. Bétail. c. r. Cong. 1907, p. 144.

Cottier[1] on the dried marc, and by Füchs[2] on the cake are of interest as showing the amount of food material often allowed to go to waste in the manufacture of grape juice or wine:

COMPOSITION OF SEEDS, MARC, AND CAKE

	Samples	Water	Protein	Fat	N-f. ext.	Fiber	Ash
Seed:	31	%	%	%	%	%	%
Min.		9.5	8.8	8.5	25.1	28.0	1.9
Max.		20.0	11.3	14.8	35.0	41.7	5.3
Marc:							
Sémichon							
Min.		8.0	11.45	5.5	40.0*	....	...
Max.		10.0	11.45	5.5	41.0*	....	...
Cottier.		6.0	8.9	7.6	52.8†	19.8	4.9
Cake.		10.0	12.0	5.0	33.0	36.0	3.0

* Carbohydrates; includes 1.5% sugar. † Sugar 14.2.

Pritzker and Jungkunz[3] secured a yield of 7.1 per cent of oil by hot-pressing grape seeds before fermentation and 11.1 to 13.8 per cent after fermentation. The protein content was within the limits shown in the above table.

Composition of Raisins and Currants.—Bornträger[4] reports on Mediterranean samples as shown in the table below:

COMPOSITION OF RAISINS AND CURRANTS (BORNTRÄGER)

	Samples	Dirt	Water	Acids	Sugars*	Ash
		%	%	%	%	%
Muscatel (Spain):	13					
Min.		0.02	21.80	1.06	62.78	1.13
Max.		0.06	28.48	1.45	67.76	2.12
Zibibbo (Italy).	1	0.07	26.06	1.31	67.10	1.50
Palestine:	7					
Min.		0.04	19.75	0.83	66.03	1.25
Max.		0.61	25.72	1.62	73.57	1.80
White (Syria):	8					
Min.		0.05	.....	0.75	59.20	1.58
Max.		0.21	.....	1.24	64.38	2.10
Currants (Zanti).		0.23	.....	1.44	66.03	1.72
Currants (S. Maura).		0.09	.....	1.44	66.03	1.94

*21 samples invert sugar only, 5 samples (including currants) levulose exceeds dextrose, 3 samples dextrose exceeds levulose, 1 sample considerable excess of dextrose.

[1] Prog. agr. vit. 1929, **91**, 595.

[2] Chem. Ztg. 1911, **35**, 30.

[3] Mitt. Lebensm. Hyg. 1930, **21**, 53.

[4] Z. Unters. Nahr.-Genussm. 1899, **2**, 257.

The edible part of 3 samples of American raisins, doubtless from California, as given in Atwater and Bryant's Compilation,[1] contained: water 7.1 to 21.0, aver. **14.6**; protein 2.3 to 3.0, aver. **2.6**; fat 0.5 to 7.2, aver. **3.3**; nitrogen-free extract and fiber 71.3 to 78.8, aver. **76.1**; and ash 2.0 to 5.0, aver. **3.4** per cent.

Changes in Composition during Ripening.—It has long been known that sugar increases and acid decreases during ripening. For example, Haas [2] found an increase of total sugar in the juice from 2.79 to 21.60 per cent and a decrease of acid calculated as tartaric from 3.69 to 0.71 per cent. Barth,[3] also working on the juice, found an increase of total sugar from 1.44 to 15.24 per cent and a decrease of acid from 3.29 to 0.84 per cent. In each of these instances the results are averages for 2 varieties and the period covered was about 2 months. Cillis and Odifredi [4] secured results comparable with the foregoing, although for a slightly shorter period of ripening, the average increase in sugars being from 1.16 to 9.61 per cent and the decrease in acid from 3.18 to 1.86 per cent.

Brunet [5] shows that the free tartaric acid decreases while cream of tartar increases during ripening. He found that the ratio of dextrose to fructose in the green grape was 3:1, changing to 1:1 during ripening and to 1:1 + during over-ripening. Garino-Canina[6] and Ferré [7] show that the loss of acidity during ripening falls almost entirely on the malic acid, the tartaric acid remaining nearly constant. Ferré notes the change of malic to lactic acid during the fermentation of wine.

Baragiola and Godet [8] review the literature and record in detail the results of their studies on the changes during ripening and wine manufacture. Proximate analyses of the juice expressed on ten dates from August 27 to October 27 are reported by the authors but the trend is well shown by four analyses given herewith, the figures in parentheses being the percentages of juice in the fruit. See table next page.

Analyses of the ash of the juice on the first and last dates are given under Mineral Constituents.

Bioletti, Cruess, and Davi,[9] in ripening experiments with several varieties of the European type during 1914 to 1916, determined, in

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[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] Z. Nahrungsm. Unters. Hyg. Waarenk. 1893, **7**, 17.

[3] Forschungsb. Lebensm. 1894, **1**, 205.

[4] Staz. sper. agr. ital. 1896, **29**, 685.

[5] Rev. vit. 1912, **37**, 15.

[6] Ann. accad. agr. Torino 1914, **50**, 233.

[7] Ann. fals. 1928, **21**, 75.

[8] Landw. Jahrb. 1914, **47**, 249.

[9] Univ. Calif. Pub. Agr. Sci. 1918, **3**, 103.

COMPOSITION OF MUST AT DIFFERENT STAGES (BARAGIOLA AND GODET)

(Results in grams per liter)

	Sp. gr.	Solids	Protein	Protein, pure	Invert sugar	Acids, fixed	Acids, volatile	Ash
Aug. 27 (76%)	1.028	72.6	2.94	1.38	25.8	33.4	0.06	2.80
Sept. 16 (83%)	1.046	118.8	4.19	2.06	78.8	25.7	0.07	2.84
Oct. 8 (77%)	1.055	143.7	5.38	3.81	55.5	17.5	0.05	3.11
Oct. 27 (75%)	1.053	138.5	5.75	4.06	53.4	18.3	0.08	3.16

addition to solids and sugar, total acid calculated as tartaric, cream of tartar, and free tartaric acid, the latter being obtained by subtracting from the percentage of total acid the percentage of cream of tartar expressed in terms of the acid. The nature of the progressive changes is well illustrated by selected results on the Muscat grape. Attention is called to the increase of acidity due to an increase in free acid during the early stages of growth.

COMPOSITION OF MUSCAT GRAPE JUICE DURING GROWTH AND RIPENING (BIOLETTI ET AL.)

(Results in grams per 100 cc.)

	Sp. gr. 15.5° C.	Solids	Protein	Sugar	Total acid as tartaric	Cream of tartar	Free tartaric acid
		%	%	%	%	%	%
June 12	1.0203	5.35	0.38	0.91	2.93	0.65	2.71
July 10	1 0195	5.14	0.36	1.33	3.60	0.55	3.38
Aug. 7	1.0582	16.58	0.55	12.72	1.60	0.73	1.31
Sept. 5	1.1023	29.36	0.65	23.28	0.60	1.17	0.13
Sept. 26	1.1133	32.89	0.59	26.68	0.56	1.39	0.00

Copeman and Frater,[1] reporting on extensive studies involving 6 varieties of grapes, show that at maturity the increase in sugar and in mineral matter comes to a practical standstill. The nitrogenous constituents appear to be formed from ammonia compounds which consequently reach a minimum at ripeness. The authors lay stress on the sugar-solids and acid-sugar ratios which at maturity vary with the variety.

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[1] Union S. Africa Dept. Agr. Sci. Bul. 1926, **50**, 54.

Hugues,[1] in experiments conducted in France during an exceptionally dry season, found that tartaric and malic acids, when calculated to the weight of the grapes, decreased during ripening but only the malic acid decreased when calculated to 1000 grapes, tartaric acid remaining practically constant.

Heiduschka and Pyriki[2] confirm the results of earlier investigators as to the decrease in total acidity during ripening but find that citric acid, which in the unripe fruit varies from 0.04 to 0.199 gram per kilo, remains practically unchanged.

Experiments by Moreau and Vinet[3] brought out a decrease in acid and a strongly marked increase in sugars during the week when the chlorophyl disappeared, also a decrease in the ratio of dextrose to levulose which continued through another week when the percentages of the two were about equal.

Influence of Soil Fertility and Storage on Composition.—De Villiers[4] was unable to correlate soil fertility or keeping qualities with chemical composition of the fruit. During storage the acidity did not decrease or the sugar-acid ratio change to any considerable degree.

Respiration.—Gore,[5] working with 3 varieties, noted a maximum evolution of 55 mg. of carbon dioxide per kilo per hour at 34.2° C. and a minimum of 2 mg. at 2.9° C. De Villiers[6] notes that temperatures above 40° C. at first increased but finally retarded respiration.

Fatty Oil of Seed.—The analyses of the seed above given show the total amount of oil which may be obtained by extraction. The actual yield, variously stated from 5 to 22 per cent, depends on the raw material and the process. Naturally the yield by cold or hot pressing is much less than by extraction; consequently the cake, because of the higher content of oil, is of greater value as a cattle food.

Physical and Chemical Values.—In the following table the range of the early results compiled by Rabek[7] and of recent results are separately given. In the latter case the samples represented are 5 by Marre,[8] 1 by Darner,[9] 46 by André and Canal,[10] 19 by Carrière and Cros,[11] 31 by Margaillan and Rabelle,[1] 1 by Pritzker and Jungkunz,[2] and 1 by Otin and Dima.[3] The last-named authors, employing the Normann method, obtained a hydroxide number of 34.82.

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[1] Ann. fals. 1929, **22**, 463.

[2] Z. Unters. Lebensm. 1929, **58**, 378.

[3] Compt. rend. acad. agr. France 1932, **18**, 198.

[4] S. Africa J. Nat. Hist. 1929, **6**, 315.

[5] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[6] Union S. Africa Dept. Agr. Sci. Bul. 1926, **45**, 6.

[7] J. Ind. Eng. Chem. 1919, **13**, 919.

[8] Rev. gén. chim. 1911, **14**, 186.

[9] N. Dakota Agr. Exp. Sta. 1913, Spec. Bul. **2**, 370.

[10] Ann. off. nat. comp. liq. 1927, **2**, 585.

[11] Ibid. 1927, **2**, 601.

VALUES FOR EUROPEAN GRAPE SEED OIL

	Sp. gr. 15° C.	Refr. index 25° C.	Solid. point ° C.	Maumené No.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Acetyl No.	Fatty acids, titer ° C.
Early results:									
Min.	0.921	1.4713	−13	52.0*	178.3	94.0	0.4*	23.2*	15*
Max.	0.956	1.4760	−10	83.0*	195.3	142.8	1.9*	144.5*	20*
Recent results:									
Min.	0.912	1.4681	....	81.5	176.1	86.2	0.2	4.0	...
Max.	0.962	1.4766	....	82.5	208.0	157.0	0.8	81.1	...

* Compiled by Lewkowitsch who queries maximum result for acetyl number.

Composition.—The following figures obtained by "K.P."[4] and by Otin and Dima[5] for the European oils (recalculated in the latter case) and by Darner[6] for oil obtained from seeds of the European type grown in California should be compared with those by Rabak and by Beal and Beebe given under American Grape:

	K. P.	Darner	O. and D.
	%	%	%
Glycerides of:			
Stearic acid	0.9	1.0	2.3
Palmitic acid	7.9	8.6	6.5
Oleic acid	34.5	29.0	32.4
α-Linolic acid	54.0	59.8	37.5
β-Linolic acid			8.0
Linolenic acid	......	......	0.2
Hydroxy acids	......	......	12.3
Unsaponifiable matter	2.7*	1.6*	0.6
	100.0	100.0	99.8

* By difference.

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[1] Loc. cit.

[2] Loc. cit.

[3] Allgem. Oil-Fett Ztg. 1934, **31**, 107.

[4] Seifenfahr. 1913, **33**, 717, 741.

[5] Loc. cit.

[6] Loc. cit.

Acids.—The presence of both *tartaric* and *malic acids* in grapes and the gradual loss of malic during ripening have been discussed under Changes in Composition during Ripening.

Citric, succinic, and *lactic acids* have been reported in the mature berry. Kunz[1] was unable to detect citric acid in the must but found it in natural wines in minute quantities. Schaffer and Gury[2] found as high as 0.08 per cent of citric acid in wine while Mayrhofer[3] found none. Schindler and Hulač[4] refer to the natural occurrence of lactic acid and consider that it improves the wine of northern grapes but not of southern grapes, which are low in acid. In judging wines the ratio of lactic to other acids should be taken into account.

Glyoxalic acid and related acids occur in the unripe berry. Sémichon and Flanzy[5] regard the presence of glyoxylic and other aldehyde acids as indexes of maturity; oxalic acid was not found in fresh must.

Hexuronic Acid.—A hexuronic acid, melting at 165° C., isolated by Cahill[6] from the purple wine grape, although resembling ascorbic acid in certain properties, differs in that it lacks antiscorbutic action.

Carbohydrates.—See American Grape.

Sorbitol.—Reif[7] found sorbitol, an alcohol derived from dextrose, in raisins and Xanti currants but not in wine grapes.

Pectins.—See American Grape.

Tannin.—Results on tannin in wine are numerous but there is some question as to whether they are representative of pure wine or the must. Garino-Canina[8] found no tannin in the red and white wines he tested, thus emphasizing the value of tests as a means of detecting added tannin. His criticism of analytical methods throws doubt on the accuracy of earlier results. He states that enin chloride gives most of the reactions of the tannins but is less astringent and of a different color.

Phosphorus-Organic Compounds.—Musts were found by Finzi[9] to contain 1.19 to 1.47 per cent of organic phosphorus calculated as lecithin, or about one-half of the total phosphorus, wines 0.165 to 0.413 per cent.

[1] Arch. Chem. Mikrosk. 1914, **7**, 285.
[2] Mitt. Lebensm. Hyg. 1915, **6**, 247.
[3] Arch. Chem. Mikrosk. 1912, **5**, 73.
[4] Chem. Listy 1929, **23**, 73.
[5] Rev. vit. 1933, **79**, 197.
[6] Bul. soc. chim. biol. 1933, **15**, 1462.
[7] Z. Unters. Lebensm. 1934, **68**, 179.
[8] Staz. sper. agr. ital. 1924, **57**, 245.
[9] Ibid. 1914, **47**, 337.

Colors.—Willstätter and Zollinger [1] extracted from the skin of dark-colored European grapes the pigment *enin*, a monoglucoside of dimethyl delphinidin, and from it prepared enin chloride, $C_{23}H_{25}O_{12}Cl + 4H_2O$, as red-brown prisms with a green luster. On hydrolysis by boiling with hydrochloric acid, it yielded 1 molecule of glucose and 1 molecule of enidin chloride, $C_{17}H_{15}O_7Cl + 1.5H_2O$, the latter forming dark brown prisms and needles with a bronze-like luster. From this in turn, 2 methyl groups were split off leaving delphinidin. In a later paper [2] the authors state that more or less of the sugar-free anthocyanidin, enidin, is present, also probably in some varieties a diglucoside. Anderson,[3] in the variety Seibel, a hybrid of *V. vinifera*, *V. æstivalis*, and *V. rupestris*, and Anderson and Habenhauer,[4] in the variety Isabella believed to be a hybrid of *V. Labrusca* and *V. vinifera*, identified enin inherited from the European parent.

Enzymes.—De Villiers [5] has shown that the *catalase* activity increases up to near ripeness when it diminishes slightly, while the *oxidase* activity diminishes during the ripening period, paralleling in general the respiration changes.

Mineral Constituents.—Results calculated to the fresh fruit by Wolff [6] and Bioletti [7] are tabulated below:

	Ash	K_2O	Na_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%
Wolff	0.88	0.50	0.01	0.10	0.04	0.14	0.05	0.03	0.01
Bioletti:									
Min.	0.45	0.19	0.01	0.02	0.01	0.08	0.01	0.02	0.00
Max.	0.66	0.35	0.06	0.03	0.02	0.18	0.03	0.03	0.02

König [8] reports instructive ash analyses of parts of the grape from which the following figures were calculated:

	Water	Ash	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_3O_4	P_2O_5	SO_3	SiO	Cl
	%	%	%	%	%	%	%	%	%	%	%	%
Skin.	73.0	0.83	0.40	0.03	0.13	0.03	0.012	0.005	0.16	0.05	0.02	0.005
Seed.	41.0	0.91	0.28	0.03	0.31	0.08	0.005	0.003	0.22	0.02	0.01	0.003
Juice.	75.0	0.38	0.25	0.01	0.02	0.02	0.006	0.002	0.05	0.02	0.01	0.004

---

[1] Ann. 1915, **408**, 83.

[2] Ibid. 1916, **412**, 195.

[3] J. Biol. Chem. 1924, **61**, 685.

[4] J. Am. Chem. Soc. 1926, **48**, 2997.

[5] Loc. cit.

[6] Aschenanalysen.

[7] California Agr. Exp. Sta. Rep. 1893/4, p. 322.

[8] Chem. mensch. Nahr.-Genussm., Berlin, 1920, **2**, 880.

Brunet[1] gives complete analyses of the skin and seeds showing, in harmony with the above figures, more phosphoric acid but less potash in the seeds than in the skin.

Ash analyses were made on the juice of the European grape by Baragiola and Godet[2] on August 27 (I) and October 27 (II), the results being expressed as grams per liter. The figures given in the original are in terms of ions but those herewith have been recalculated to oxides:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Al_2O_3	Mn_2O_3	CuO	P_2O_5	SO_3	SiO_2	Cl	CO_2
I..	1.178	0.090	0.360	0.172	0.038	0.004	0.004	0.022	0.274	0.125	0.017	0.007	0.543
II..	1.499	0.086	0.235	0.116	0.023	0.002	0.004	0.011	0.524	0.197	0.026	0.013	0.466

Minor Mineral Constituents. *Iron.*—California grapes 49 to 98 mg. per kilo, recalculated from Fe_2O_3 of ash analysis (Bioletti).[3] Fruit 13 mg. per kilo, fresh basis (Bunge, quoted by Sherman).[4] Seeded raisins 36 mg. per kilo, as sold (Sherman).[4] Malaga grapes 22.8 mg. per kilo, fresh basis; seeded raisins 69.9, seedless raisins 41.3, dried Xanti currants 47.4 mg. per kilo, as sold (Peterson and Elvehjem).[5] Malaga grapes, 2 samples, 5.4, 7.1 mg. per kilo, fresh basis (Toscani and Reznikoff).[6]

Aluminum.—White grapes 10.2 mg. per kilo, dry basis (Bertrand and Lévy).[7]

Manganese.—California grapes 7.2 to 14.0 mg. per kilo, recalculated from Mn_3O_4 of ash analysis (Bioletti).[3]

Copper.—Grapes 1.2 mg. per kilo, fresh basis, 9.9 mg. per kilo, dry basis (Guérithault).[8] Malaga grapes 0.9 mg. per kilo, fresh basis; seeded raisins 2.7, seedless raisins 2.0 mg. per kilo, as sold (Lindow, Elvehjem, and Peterson).[9]

Zinc.—Whole grapes: white 2, black 1.2 mg. per kilo, fresh basis; nearly seedless dry Malaga 2 mg. per kilo (Bertrand and Benzon).[10]

[1] Loc. cit.

[2] Loc. cit.

[3] California Agr. Exp. Sta. Rep. 1894, p. 322.

[4] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

[5] J. Biol. Chem. 1928, **78**, 215.

[6] J. Nutrition 1934, **7**, 79.

[7] Bul. soc. hyg. aliment. 1931, **19**, 359.

[8] Compt. rend. 1920, **171**, 196.

[9] J. Biol. Chem. 1929, **82**, 465.

[10] Bul. soc. hyg. aliment. 1928, **16**, 457.

FRUITS OF THE ELÆOCARPUS FAMILY

(*Elæocarpaceæ*)

ONLY one fruit, datiles, is here described.

DATILES

Muntingia Calabura L.

Although a native of tropical America, the tree is cultivated in the East Indies. Pratt and Del Rosario state that in the Philippines it grows abundantly and the fruit is eaten largely by children. Other names mentioned by them are *ratiles*, *cerezas*, and *manzanitas*.

The description which follows is based on an examination of material furnished by Miss Maria Orosa of the Philippine Bureau of Science.

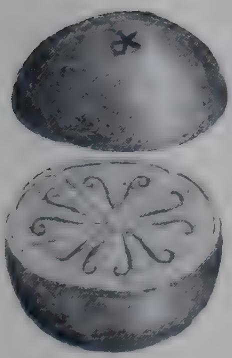

FIG. 261.

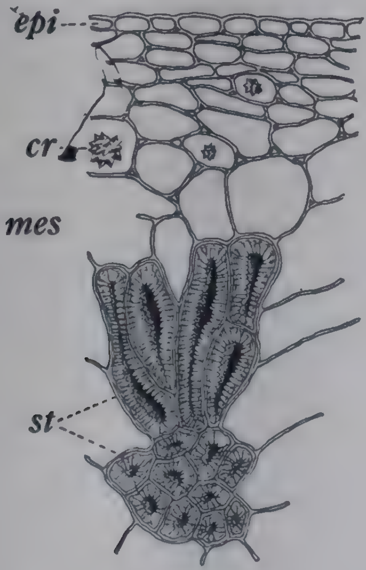

FIG. 262.

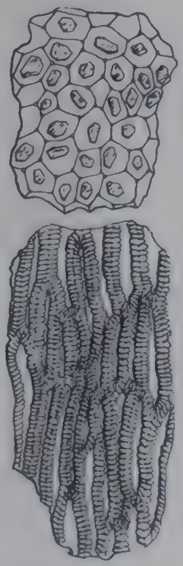

FIG. 263.

FIG. 261.—Datiles. Fruit cut to show five locules and numerous minute seeds on recurved placentæ. × 2. (A.L.W.)

FIG. 262.—Datiles. Outer layers of fruit in cross section. *epi* epicarp; *cr* rosette crystals; *mes* mesocarp parenchyma with *st* stone cell group. × 160. (K.B.W.)

FIG. 263.—Datiles. Outer epiderm with crystals and sclerenchyma layer of spermoderm in surface view. × 160. (K.B.W.)

MACROSCOPIC STRUCTURE.—The *flowers* are white with superior, five- or six-celled ovary. The *fruit* (Fig. 261) is globular, up to 1.5 cm. long, crowned with the five or six radiating, sessile stigmas. Each of the locules, formed by the rind and the thin partitions, is filled with numerous minute (0.5 mm.) *seeds*, borne in a gelatinous pulp on pairs of recurved axile placentæ.

MICROSCOPIC STRUCTURE.—Four layers of **Pericarp** (Fig. 262) are evident, but the fifth or endocarp is lost in the confused mass of pulp and seeds: (1) *epicarp* (*epi*) of polygonal cells, containing coloring matter, and occasional stomata; (2) *hypoderm* of small flattened cells passing into (3) *outer mesocarp* (*mes*) of large parenchyma cells, those about the groups of stone cells (*st*) forming rosettes; and (4) *inner mesocarp* of very thin-walled round cells surrounding the seeds.

Oxalate rosettes (*cr*) occur in the hypoderm and outer mesocarp, especially where the latter passes into the inner mesocarp.

Spermoderm (Fig. 263).—On crushing the seeds, three tissues are evident: (1) *outer epiderm* of isodiametric, exceedingly thin-walled, polygonal cells, slightly thickened at the angles, each containing a single monoclinic oxalate crystal; (2) longitudinally elongated, very thick-walled *stone cells* with fine pores ending in round holes at the middle lamella; (3) *rounded parenchyma* cells with no sharp differentiation into an inner epiderm.

The **Endosperm** and straight **Embryo** are starch-free.

CHIEF STRUCTURAL CHARACTERS.—Fruit up to 1.5 cm., crowned with radiating sessile stigmas, locules five or six with minute (0.5 mm.) seeds.

Mesocarp with stone cell groups and oxalate rosettes. Spermoderm with an outer epiderm containing single oxalate crystals and subepiderm consisting of stone cells. Endosperm and embryo starch-free.

CHEMICAL COMPOSITION.—The edible pulp, including seeds, of a sample grown in the Philippines, as analyzed by Pratt and Del Rosario,[1] contained as follows:

COMPOSITION OF DATILES PULP

Weight	Pulp in fruit	Solids, total	Solids, insol.	Protein	Acids as malic	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
g. 1.5	% 80	% 24.6	% 8.4	% 1.98	% 0.08	% 8.05	% 5.34	% 0.80	cc. 96

* Cc. *N*/10 acid per 100 grams pulp.

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[1] Philippine J. Sci. 1913, **8**, 59.

FRUITS OF THE MALLOW FAMILY

(*Malvaceæ*)

To THIS family, which furnishes us with flowers (hollyhock, althea), a vegetable (okra), and fiber and oil seeds (cotton), belongs a fruit, roselle, which is unique in that the calyx is the part eaten.

ROSELLE

Hibiscus Sabdariffa L.

The roselle is grown throughout the tropics and sub-tropics. The leaves may be eaten as a pot herb and the fiber has some value, but the plant is cultivated chiefly for the calyx which is used in the preparation of jam resembling somewhat that of the cranberry in its acid flavor.

MACROSCOPIC STRUCTURE.—The yellow *flower*, on the plan of five, has a bright red calyx and bracts; there is a yellow variety but it does not give the desired red color to the cooked product. After flowering, the *calyx* enlarges to form what appears like a large flower bud up to 6 cm. in length.

MICROSCOPIC STRUCTURE.—No data available.

CHEMICAL COMPOSITION.—In the following table are results on an American sample by Wester,[1] on a Philippine sample by Pratt,[2] and on a Hawaiian sample by Thompson:[3]

COMPOSITION OF ROSELLE

	Water	Solids, insol.	Protein	Fat	Acids as malic	Benzoic acid	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Wester...	88.91	6.67	......	.....	2.77	0.00	0.33	0.03	....	0.89
Pratt....	82.49	7.39	......	.....	3.31	0.00	0.82	0.24	....	1.26
Thompson	88.42	5.03	1.23	0.82	3.11	....	0.20	0.00	1.45	0.65

---

[1] U. S. Dept. Agr. 1907, Farm Bul. **307**.

[2] Philippine J. Sci. 1912, **7**, 201.

[3] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

In the calyx (49.52 per cent) and pod (50.48 per cent) Woods and Merrill[1] found respectively: water 86.5 and 84.0, protein 2.1 and 1.7, fat 0.3 and 1.0, carbohydrates 10.3 and 12.2, and ash 0.8 and 1.1 per cent.

Acids.—Pratt[2] notes that the *malic acid* consists entirely of the dextrorotatory form, never before isolated in plants.

---

[1] Maine Agr. Exp. Sta. 1901, Bul. 75.

[2] Loc. cit.

FRUIT OF THE BOMBAX FAMILY

(*Bombacaceæ*)

This family is closely related to *Malvaceæ*. Only one species (durian) is here described. From *Pachira aquatica* Aubl. is prepared a commercial starch (see Volume I, Commercial Starches), from *Eriodendron anfractuosum* DC. and *Bombax Ceiba* L. edible oil and cake (see Volume I, Kapok Seed).

DURIAN

Durio zibethinus L.

Fr. Dourian. Ger. Durion.

Of the several species of *Durio*, *D. zibethinus* is by far the most important. All are natives of the Malay region where the durian has long been a staple food of the natives and a much-prized delicacy of such Europeans as could bring themselves to try it. The odor suggests a mixture of cheese, rotten onions, and turpentine. On ripening, the heavy spiny fruit falls and is a serious menace to anyone beneath the tree. The whole unripe fruit is boiled as a vegetable, the custard-like arils of the ripe fruit are eaten out of hand, and the mature seeds are roasted.

MACROSCOPIC STRUCTURE.—The *fruit* is green, hard, tough, round to ovoid, up to 25 cm. long, weighs several kilograms, and is covered with short, blunt spines. It is five-celled and each cell is several-seeded. The ovoid anatropous *seed* is up to 4 cm. in length, with thick, soft, light-colored aril, thin, leathery, brown spermoderm, and two straight, bulky cotyledons between which is the small straight radicle.

MICROSCOPIC STRUCTURE.—Material preserved in formaldehyde was furnished by Mr. S. Danial, Senior Health Inspector, Ipoh, Federated Malay States.

Pericarp.—In cross section five distinct tissues are evident: (1) *epicarp* of rounded-polygonal, thin-walled cells and numerous scales; (2) *hypoderm* of one or more layers of small thin-walled, rounded cells; (3) *fiber zone* of white, porous, tangentially elongated fibers, varying in size and shape, with walls varying from thinner to thicker than the lumen; (4) *mesocarp* of thin-walled parenchyma with numerous oil drops and small vascular bundles; and (5) *endocarp* of thin-walled, more or less elongated, narrow parenchyma cells with here and there single cells or small groups with sclerenchymatized and porous walls.

The rosette-like *scales* consist of more or less elongated, radiating component cells with thick, white, sometimes porous, walls and brown contents. The marginal cells are more or less free, standing out like a fringe of hairs.

Aril.—This bulky appendage of the seed is made up of three tissues: (1) *outer epiderm* of more or less elongated cells with thin, indistinctly beaded walls, (2) mass of very thin-walled parenchyma with numerous small oil drops and occasional delicate vascular bundles, and (3) *inner epiderm* similar to the outer but with walls slightly thicker. Griebel[1] reports the presence of erythrodextrin and mannite in the parenchyma.

Spermoderm.—Although lacking hairs, the spermoderm suggests that of species of *Malvaceæ* in which family the durian was formerly included.

There are five layers: (1) *outer epiderm* of small, thin-walled, rounded-polygonal cells, with striated cuticle; (2) *outer brown coat*, many cells thick, of thin-walled spongy parenchyma, through which run delicate raphe bundles; (3) thick-walled *palisade cells*, about 27 μ high, with top-shaped cavity in outer half; (4) *inner brown coat* of transversely elongated, more or less collapsed parenchyma in the middle of which is a row of enormous, transversely elongated (over 1 mm.) mucilage cells; and (5) ill-defined, thin-walled *inner epiderm*.

Perisperm and **Endosperm** not evident.

Cotyledon.—There are three layers: (1) *outer epiderm* of small, brown-walled cells, often narrow, much elongated, and arranged side by side; (2) *mesophyl* of thin-walled starch parenchyma and numerous oleoresin cavities; and (3) *inner epiderm* of small, colorless cells.

The *starch grains* are spherical or truncated, up to 19 μ, facets of many indicating earlier grouping in aggregates.

CHIEF STRUCTURAL CHARACTERS.—Fruit green, rounded-ovoid, spiny, up to 25 cm. long, five-celled, each several seeded. Seed, up to 4 cm., with bulky aril and cotyledons.

Pericarp with rosette-like scales, fiber layer, and oily mesocarp. Aril with oil drops. Spermoderm with large mucilage cells. Cotyledons with starch cells and oleoresin cavities; starch grains spherical or truncated, up to 19 μ.

CHEMICAL COMPOSITION.—The edible part of a sample grown in the Philippines, as analyzed by Pratt and Del Rosario,[2] contained as follows:

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[1] Z. Unters. Lebensm. 1928, **55**, 89.

[2] Philippine J. Sci. 1913, **8**, 59.

COMPOSITION OF EDIBLE PART OF DURIAN

Weight	Edible part in fruit	Solids	Protein	Acids as citric	Sugars, reducing	Sucrose	Starch	Ash, total	Ash, alk.*
g.	%	%	%	%	%	%	%	%	cc.
2250	30	44.5	2.31	0.19	4.29	8.97	11.1	1.24	130

* Cc. $N/10$ acid per 100 grams pulp.

The odor suggests the presence of oil of garlic and butyric acid but laboratory evidence is lacking.

FRUITS OF THE GARCINIA FAMILY

(*Guttiferæ*)

THE mangosteen and the mamey, one oriental, the other occidenta are the edible representatives of this family.

COMPARATIVE MACROSCOPIC STRUCTURE.—The edible par of both fruits is the *inner mesocarp* which in the mangosteen separate more readily from the outer mesocarp than in the mamey. In th mangosteen there are four sepals and several radiating sessile stigma persisting in the fruit; in the mamey the calyx is entire in the bud splitting into two valves as the flower opens and separating later from the fruit. Only the mamey has a hard endocarp about the locules. Th bulk of the embryo in the mangosteen is radicle, in the mamey cotyledons

COMPARATIVE MICROSCOPIC STRUCTURE.—Characteristi of both species are schizogenic *oleoresin ducts* present in the mesocar These also occur in the cotyledon of the mamey. Separation of oute and inner mesocarp is through a tissue of flattened, thin-walled cells *Oil* is the chief reserve material in the radicle of the mangosteen, *starc* in the cotyledons of the mamey.

COMPARATIVE CHEMICAL COMPOSITION.—The fruits ar rich in sugars and mildly acid.

MANGOSTEEN

Garcinia Mangostana L.

Fr. Mangoustan. Sp. Mángostan. It. Mangostana. Ger. Mangostan

Fairchild, the recognized authority on this remarkable fruit, i unstinted in his praise of the superlative beauty of its parts and th deliciousness of its flavor. Its merits, however, have been tested b comparatively few Europeans, since the cultivation of the tree has no been successful outside of Malaysia and the Malay Peninsula, wher it is native, Ceylon, and India, except in a few localities such as Puert Rico whence the sample examined was obtained through the courtesy Prof. H. T. Cowles.

The rind is astringent and is used as a drug in India. A relativ is the gamboge tree (*G. Morella* Desr.).

MACROSCOPIC STRUCTURE.—Staminate and perfect *flowers* are borne on the same or separate trees. Both are red or pink, about 5 cm. in diameter, and have four sepals and four fleshy petals. The superior ovary has four to eight sessile radiating stigmas and the same number of cells, with solitary ovules of which only a part, or none, develop into seeds.

The *fruit* (Fig. 264) is purple-red and varies up to 6 cm. in diameter. It is crowned by a rosette formed by the flattened stigmas and bears the persistent sepals at the base. Cut transversely, the tough rind or outer mesocarp, about 5 mm. thick, is of a pink color and from it yellow drops of volatile oil exude. If care is taken in cutting, the upper half of the rind may be removed as a cap exposing the edible segments or inner mesocarp. These are white or cream-colored, translucent, and delicately veined, the general direction of the veins on the surface being longitudinal, while within, as seen in cross section, they also radiate from the seed. The *seed* is irregular, flattened, and consists largely of radicle, the cotyledons being minute.

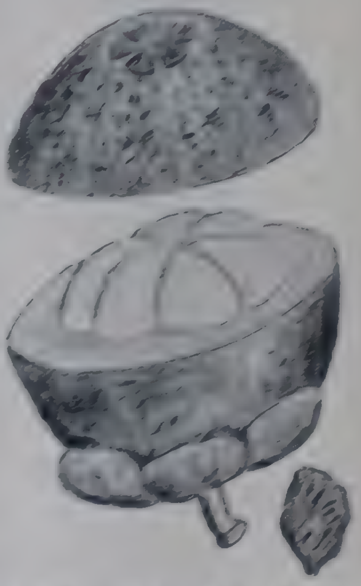

Fig. 264.—Mangosteen. Fruit cut to the edible segments. Below, a seed. × ½. (A.L.W.)

MICROSCOPIC STRUCTURE.—Since the rind is a drug, the **Pericarp** has been studied by several authors. It consists of (1) *epicarp* of small, isodiametric cells and numerous stomata; (2) *hypoderm* of several rows of more or less collapsed cells; (3) *stone cell zone*, the individuals being rounded with brown contents; (4) *outer mesocarp* of soft, somewhat spongy ground tissue often beaded and interspersed with numerous oleoresin ducts and fibro-vascular bundles; (5) edible *inner mesocarp* (Fig. 265) of thin-walled, mostly elongated cells, numerous dark, branching oleoresin ducts and accompanying elongated parenchyma cells both with dark contents forming the veins, and occasional colorless fibro-vascular bundles; and (6) *endocarp* of inconspicuous thin-walled cells.

The *oleoresin ducts* are schizogenetic and characteristic of the family. In addition to the elongated cells accompanying the bundles, are others still more strongly elongated, many times longer than broad, radiating from the seeds.

Spermoderm.—Differentiation into layers is not evident. The cells are dark, with resin, and compressed. The vessels of the raphe often have as many as six strands of spiral thickenings.

Endosperm.—Not evident.

Embryo.—The ground tissue of the *radicle* (Fig. 266) consists of distinctly porous (beaded) cells containing drops of oil (*ol*) and occasional starch grains (*am*) up to 5 μ, also smaller non-porous cells each nearly filled by a crystal rosette (*cr*) up to 60 μ or larger.

Chief Structural Characters.—Fruit red with sessile radiating stigmas at top and four sepals at base; rind pink on cut surface, separating from whitish, translucent, veined, edible inner mesocarp. Spermoderm brown, thin; embryo largely radicle.

Stone cell zone beneath hypoderm; outer and inner mesocarp with branching oleoresin ducts. Radicle with porous cells containing oil and starch and non-porous cells containing oxalate rosettes.

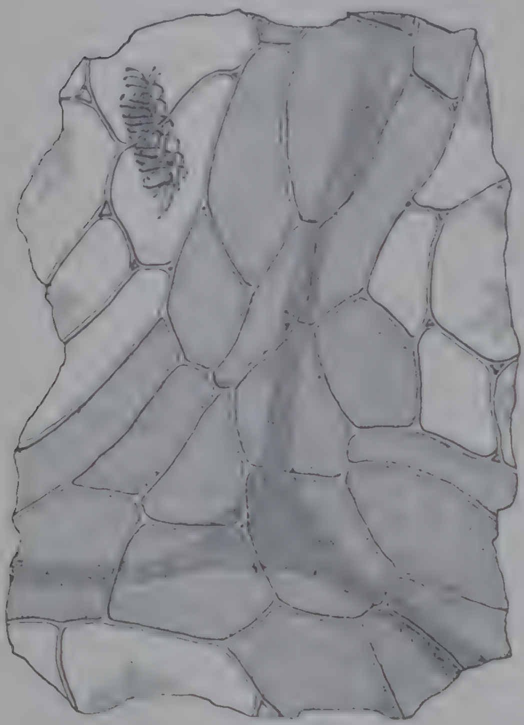

Fig. 265.

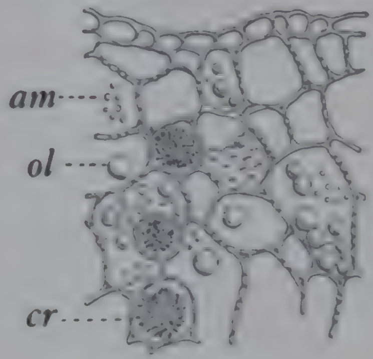

Fig. 266.

Fig. 265.—Mangosteen. Edible pulp in surface view showing branching bundle of dark cells surrounding oleoresin duct and spiral vessels, one with several strands, from fibro-vascular bundle. × 160. (K.B.W.)

Fig. 266.—Mangosteen. Radicle in cross section. *am* starch grains; *ol* oil drop; *cr* crystal rosette. × 160. (K.B.W.)

CHEMICAL COMPOSITION.—The edible pulp of a sample grown in the Philippines, as analyzed by Pratt and Del Rosario,[1] contained as follows:

Composition of Edible Part of Mangosteen

Weight	Edible part in fruit	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
g.	%	%	%	%	%	%	%	%	cc.
100	31	19.8	1.9	0.50	0.49	4.20	12.63	0.23	29

* Cc. $N/10$ acid per 100 grams pulp.

[1] Philippine J. Sci. 1913, **8**, 59.

Mangostin.—From the dried resinous secretion Dragendorff[1] separated α- and β-mangostin (in the ratio of 15:1), a sterol, and a volatile oil. Both forms of mangostin are of a light yellow color. They melt respectively at 180 to 181° C. and 175.5° C. He assigns to α-mangostin the formula $C_{16}H_{16}O_4$ or $C_{16}H_{18}O_4$. Murakami[2] adopts the formula $C_{23}H_{24}O_6$ for the α form in which he finds one CH_3O group, three HO groups, and two double bonds. He also suggests a structural formula. Yamashiro[3] gives $C_{20}H_{22}O_5$, the formula first proposed by Liechti,[4] and states that one CH_3O and two HO groups are present.

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[5] reports 0.68 per cent, dry basis, in the edible portion.

MAMEY

Mammea americana L.

Fr. Abricot de Saint Domingue. Sp. Mamey de Santo Domingo.
Ger. Mammeiäpfel.

Like its Malaysian relative the mangosteen, this American tropical species is little known outside its native region. The fruit improves on cooking, the flavor resembling that of apricots. In Cuba mamey preserves are made in the household and on a commercial scale.

MACROSCOPIC STRUCTURE.—The *flowers* are white, polygamous, and about half the size of those of the mangosteen. A further distinction is that the calyx in the bud is entire, splitting into two valves when the flower opens. The petals vary up to six and the ovary is two- to four-celled but not all of the cells contain seeds at maturity. In the fruit, shown in Fig. 267, there are three locules but only one contains a seed, the others being collapsed.

The *fruit* is a drupe, the size and shape of an orange, and has a rough russet surface covered with small spots. Cut transversely, it shows the tough rind about 4 mm. thick, the yellow edible fruit flesh in which are radiating veins, and the irregular chocolate brown endocarp, 2 to 5 mm. thick, consolidated with the spermoderm. Although the outer and inner mesocarp do not fall apart as in the mangosteen, they still may be readily separated when ripe. Unlike that of the mangosteen, the embryo consists of two large fleshy cotyledons and a short radicle.

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[1] Ann. 1930, **482**, 280.

[2] Proc. Imp. Acad. (Tokyo) 1931, **7**, 254, 311; Ann. 1932, **496**, 122; J. Chem. Soc. Japan 1932, **53**, 150.

[3] Bul. Chem. Soc. Japan 1932, **7**, 1.

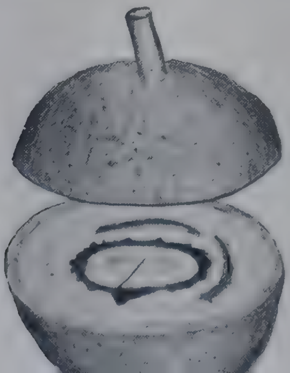
[4] Arch. pharm. 1891, **229**, 426.

[5] Philippine Agr. 1932, **21**, 53.

MICROSCOPIC STRUCTURE. Pericarp (F number five: (1) *epicarp* much torn and unrecognizable at maturity; (2) *hypoderm* (*hy*) of small cells; (3) *outer mesocarp* (mes^1) of porous-walled cells, branching oleoresin ducts (ol^1), and fibro-vascular bundles containing vessels with several spiral strands; (4) *inner mesocarp* (mes^2) of large, thin-walled pulp cells, radially elongated in the inner part, also oleoresin ducts; and (5) *endocarp* consisting of crossing bundles of fibers (f^1, f^2) with lumen broader than the walls, also small brown exceedingly thin-walled parenchyma cells (*br*), one or more thick, adjoining the mesocarp and surrounding the fiber bundles.

Between the outer and inner mesocarp are two or more rows of flattened, thin-walled cells (x) through which separation of the rind takes place easily.

Spermoderm.—While there is no separation of endocarp from spermoderm, the latter is doubtless represented by the inner zone of collapsed thin-walled brown cells.



Endosperm.—Not evident.

Embryo.—The epidermis of the *cotyledon* consist of small cells conaining minute aleurone grains, whereas the ground tissue of the mesohyl is made up of larger, porous-walled cells containing elongated tarch grains (Fig. 268, *am*) up to 55 μ, with excentric hilum. The xcentricity of the hilum ranges from 1 : 2 to 1 : 4. *Oleoresin ducts* (ol^2) re distributed through the ground tissue from which, on cutting the otyledons, minute yellow drops exude.

Chief Structural Characters.—Fruit with rough russet surface, ind grown to edible fruit flesh; endocarp hard (absent in mangosteen), rown to spermoderm; embryo largely fleshy cotyledons.

Pericarp tissues similar to those of mangosteen excepting the endoarp of crossing fiber bundles. Cotyledons containing elongated starch rains (55 μ), with excentric hilum, in ground tissue and oleoresin in ucts like those of mesocarp.

CHEMICAL COMPOSITION.—Two analyses by Chace, Tolman, nd Munson[1] of the edible part of Cuban fruit, designated Mamey de Santo Domingo, yielded:

	Weight	Edible part in fruit	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	cc.
I	623	61	14.12	4.49	0.49	0.60	3.92	5.49	0.31	43
I	502	71	15.74	.....	....	0.56	2.50	5.64	0.38	33

* Cc. N/10 acid per 100 grams fruit.

[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87.

FRUITS OF THE FLACOURTIA FAMILY

(*Flacourtiaceæ*)

Thorny trees and shrubs of two genera yield edible fruits used chiefly for preserves. In addition to the kei apple, described in the subsequent section, four other species of *Aberia* (*Doryalis* or *Dovyalis*) yield edible fruits, namely: ketembilla or Ceylon gooseberry (*A. Gardneri* Clos. = *D. hebecarpa* (Gardn.) Warb.); two kaffir plums (*D. rotundifolia* (Thunb.) Harv. and *D. rhamnoides* (Burch.) Harv.), both natives of South Africa; and the warty plum (*D. verrucosa* (Hochst.) Warb.).

Of several species of *Flacourtia*, natives of Asia and Africa, the most important is the batoko-, Madagascar-, or Governor's-plum (*F. Ramontchi* L'Her.) which has been introduced into the West Indies and Florida. Valenzuela and Wester[1] found in the edible portion of a sample from the Philippines: water 66.25, protein 1.34, fat 0.27, reducing sugar 21.74, fiber 1.40, and ash 1.05 per cent.

KEI APPLE

Aberia caffra Hook. f. et Harv. = *Dovyalis caffra* Warb.

A native of South Africa in the region of the Kei River, where it is known by the natives as the *umkokolo*, this species like others of the family is useful both as a thorny hedge shrub and for its fragrant fruits. It has been introduced into Florida and California as well as other sub-tropical regions. Being strongly acid, the fruit is best suited for preserves.

MACROSCOPIC STRUCTURE.—Like other members of the genus, the plant is diœcious, both male and female *flowers* being without petals, also the female flower has a persistent lobed calyx, an ovary with several cells formed by false partitions, and several small persistent styles. The several-seeded *berry* is globular or oval, bright yellow, 2 to 3 cm. in diameter. The *seeds* resemble in size (8 mm. long), shape, and color those of the apple but are covered with a dense coat of hairs. Within the leathery brown spermoderm is a bulky endosperm and an embryo consisting of broad but thin cotyledons and a short straight radicle.

[1] Philippine J. Sci. 1930, **41**, 85.

MICROSCOPIC STRUCTURE.—The **Pericarp** consists of (1) *epicarp* of nearly isodiametric cells and numerous unicellular, thick-walled, indistinctly warty hairs up to 50 μ; (2) *hypoderm* of thick-walled parenchyma; (3) *mesocarp* of characterless parenchyma interspersed with a few comparatively thin-walled stone cells, varying from isodiametric, often with projections, to narrow elongated, and weak fibro-vascular bundles; and (4) *endocarp* of tangentially elongated, pointed, thin-walled cells and stomata.

Spermoderm.—This is as elaborate in its structure as the pericarp is simple. Not less than seven layers are present: (1) *outer epiderm* of large brown cells, somewhat radially and tangentially elongated, with thickened outer walls, containing rounded granules, also numerous unicellular, thin-walled, kinky hairs often 300 μ long; (2) and (3) crossing layers of thin-walled elongated *parenchyma*; (4) colorless, longitudinally elongated, porous, thick-walled, flattened *sclerenchyma fibers* arranged on edge; (5) *stone cells*, often transversely elongated, forming an interrupted layer; (6) *parenchyma*; and (7) *inner epiderm* of yellow palisade cells, circular in surface view, with narrow nipple-shaped outer ends and thickened inner walls.

Endosperm.—This consists of (1) a bulky tissue of isodiametric *aleurone cells* containing aleurone grains up to 12 μ, and (2) inner *compressed cells* with thin walls.

Embryo.—The thin flattened *cotyledons* consist of noticeably small isodiametric cells containing aleurone grains somewhat smaller than those in the endosperm.

Chief Structural Characters.—Fruit 2 to 3 cm., several-celled by false partitions. Seeds pointed, brown, densely hairy. Spermoderm leathery; endosperm bulky; cotyledons thin; radicle straight.

Epicarp with short thick-walled hairs; mesocarp characterless with a few comparatively thin-walled stone cells; endocarp of elongated cells and stomata. Outer epiderm of spermoderm with large brown cells and long kinky hairs; fibers of fourth layer flattened, arranged on edge; inner epiderm of round palisade cells. Endosperm with medium-sized aleurone grains. Embryo with minute aleurone grains.

FRUITS OF THE PASSION-FLOWER FAMILY

(*Passifloraceæ*)

The species of *Passiflora* yield fruits resembling papayas and melons.

COMPARATIVE MACROSCOPIC STRUCTURE.—Most of the species are climbing and all have curious *flowers*, the parts of which are considered to be emblems of the crucifixion. On the throat of the four- or five-lobed tubular calyx are borne four or five petals and numerous fringe-like rays forming the so-called corona. The filaments are united into a narrow tube, within which is the stalk of the ovary and protruding from it are the three styles. The ovary has three parietal placentæ and ripens into a melon-like *fruit* with numerous *seeds*, each enclosed in a whitish sac-like aril.

COMPARATIVE MICROSCOPIC STRUCTURE. Pericarp.—Thin-walled epicarp hairs and spiral-reticulated cells in the rind characterize the giant granadilla, thick-walled epicarp hairs and stone cells in the rind, the purple granadilla.

Aril.—Starch occurs in the aril of the purple species.

Spermoderm.—In the giant granadilla a subepiderm is present; the third layer is of thin-walled, the fourth, of thick-walled palisade cells; in the purple granadilla a subepiderm is lacking and only the thick-walled palisade layer is present.

The **Endosperm** of both species contains aleurone grains, up to 15 μ, and the **Embryo** smaller aleurone grains.

GIANT GRANADILLA

Passiflora quadrangularis L.

Fr. Barbadine. Sp. Granadilla. It. Granatiglia. Ger. Granadille.

This American species is grown throughout the tropics and subtropics. Popenoe, who suggested the name, states that it thrives in Florida but not satisfactorily in California. The fruit is considered inferior to that of the purple granadilla.

MACROSCOPIC STRUCTURE.—The *flowers* are large and showy. The yellow-green *fruit* is elongated, reaching 25 cm., with a rind about 4 cm. thick, and brown, much-flattened *seeds*, up to 1 cm. long, not including the aril. The spermoderm is brittle and rather thick, the endosperm is bulky, and the flattened cotyledons are embedded in the endosperm.

MICROSCOPIC STRUCTURE. Pericarp.—The tissues are (1) *epicarp* of thin-walled polygonal cells and a few yellow, thin-walled, pointed, unicellular hairs up to over 200 μ; (2) *hypoderm*, a few cells thick, with faintly porous walls, containing rosette oxalate crystals; (3) *parenchyma* and *spirally reticulated cells*; (4) *outer mesocarp*, a bulky tissue of rather thick-walled, indistinctly porous parenchyma and occasional small fibro-vascular bundles; (5) *inner mesocarp* of thin-walled spongy parenchyma and numerous large fibro-vascular bundles sometimes with accompanying narrow elongated stone cells; and (6) *endocarp* of large thin-walled cells with thick cuticle.

Aril.—The cells are thin-walled and longitudinally elongated with finely granular contents staining yellow with iodine in potassium iodide.

Spermoderm.—Cross sections show: (1) *outer epiderm* of thin-walled colorless cells with delicate rod-shaped radial thickenings; (2) *subepiderm*, about two cells thick, of colorless thin-walled cells; (3) outer *thin-walled* and (4) inner porous *thick-walled palisade layer*, both with brown walls and contents, the dividing line between the two layers being sinuous; and (5) *inner epiderm* of small brown cells.

Perisperm.—Only vestiges evident.

Endosperm.—The cells contain aleurone grains up to 15 μ, each with a distinct crystalloid and one or more globoids.

Embryo.—Throughout the cells are small and isodiametric. The aleurone grains are much smaller than in the endosperm.

CHIEF STRUCTURAL CHARACTERS.—Fruit up to 25 cm., light-colored, melon-like. Aril whitish; seeds (1 cm.) brown, much-flattened; endosperm bulky; cotyledons broad and thin.

Epicarp hairs up to 200 μ, few, thin-walled; hypoderm with crystal rosettes; layer beneath hypoderm with scattered spiral-reticulated cells; outer mesocarp of parenchyma; inner mesocarp of spongy parenchyma. Aril starch-free. Spermoderm with two brown palisade layers beneath the hypoderm. Endosperm and embryo contain aleurone grains.

PURPLE GRANADILLA

Passiflora edulis Sims

Fr. Marie tambour. Ger. Apfelförmige Granadille.

The above name of this, the best known of the passion fruits, is that suggested by Popenoe. A native of Brazil, it is grown throughout the tropics and sub-tropics, including California and Florida, but especially in Australia where two crops are harvested each year. It is eaten out of hand or made into sherbets, beverages, and confections.

MACROSCOPIC STRUCTURE.—The *stem* is round and the *leaves* three-lobed. The *fruit* is somewhat elongated (up to 7 cm.), externally resembling a purple plum. The *seed*, separated from the loose aril, is nearly black, somewhat flattened, up to 6 mm. long, pitted on drying. The broad but thin cotyledons divide the endosperm into halves.

MICROSCOPIC STRUCTURE.—The **Pericarp** differs from that of the giant species as follows: the epicarp *hairs* are more numerous, shorter (up to about 100 μ), and thicker-walled; *crystal rosettes* are few in the hypoderm; the third layer is of *stone cells*, about five thick; and the cell walls of the *outer mesocarp* are thinner.

Aril.—The cells contain numerous round starch grains, up to 10μ, also twins and triplets.

The **Spermoderm** shows the following differences from that of the giant species: (1) the cells of the *outer epiderm* have more distinct rod-shaped thickenings, thicker inner walls, and where pits are formed are radially much elongated; (2) there is no evident *subepiderm*; and (3) only the thick-walled *palisade layer* is present and this has depressions causing the formation of the pits in the seed on drying.

Perisperm, Endosperm, and **Embryo.**—As in the giant granadilla.

CHIEF STRUCTURAL CHARACTERS.—Fruit up to 7 cm., deep purple. Seeds, 6 mm., somewhat flattened, pitted on drying.

Epicarp hairs up to 100 μ, numerous, thick-walled; hypoderm with few crystal rosettes; stone cells five deep form third layer. Aril with starch grains up to 10 μ. Outer epidermal cells of spermoderm radially much elongated under depressions; subepiderm lacking; only one (thick-walled) palisade layer.

CHEMICAL COMPOSITION.—Jewell[1] gives the following analysis of the pulp on the dry basis: protein 9.9, fat 7.0, acids as citric 9.5, reducing sugars 25.5, non-reducing sugars 5.4, starch 14.3, fiber 26.0, ash 2.43, K_2O 1.05, Na_2O 0.081, CaO 0.041, MgO 0.19, Fe_2O_3 plus Al_2O_3 0.067, P_2O_5 0.55, SiO_2 0.04, and Cl 0.018 per cent.

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[1] J. Dept. Agr. Victoria 1933, **31**, 609.

FRUITS OF THE PAPAW FAMILY

(*Caricaceæ*)

THIS small family is characterized by the proteolytic ferment *papayotin* ("papain") present in the latex. Papaya is the common representative. Other species of the same genus are grown in tropical and subtropical regions. The family is related to the *Passifloraceæ* and the *Cucurbitaceæ.*

The papaya is moderately high in sugars but low in *acid.*

PAPAYA

Carica Papaya L. = *Papaya vulgaris* DC.

Fr. Papaye. Sp. Papaya. It. Papaia. Ger. Melonenbaum.

The English name papaw, often used, is unfortunate since it more properly belongs to the annonaceous species *Asimina triloba,* a native of the United States. The species is a native of the New World but is now grown throughout the tropics. Although known as a tree, because of its size and trunk, the plant is herbaceous, resembling somewhat the castor bean plant. It is usually diœcious.

The dried latex, formerly known as papain (*Succus Caricæ Papayæ*), containing the proteolytic enzyme papayotin—the term " papain " is now restricted to the dried latex—is used to render tough meat tender and as a substitute for pepsin in medicine.

In addition to being served raw and cooked as a vegetable, the fruit is canned, preserved, pickled, and dried, also from it are made jellies, syrups, and extracts, the last being valuable because of the enzyme.

MACROSCOPIC STRUCTURE.—Both kinds of flowers are on the plan of five with five small sepals and a tubular corolla with five lobes. The *male flowers* have ten stamens inserted on the narrow corolla throat; the *female flowers* have a superior ovary with five sessile stigmas and corolla thickened at the base.

The melon-like *fruit* (Fig. 269) is round or elongated, up to 500 cm. long, with numerous bur-like, dark brown anatropous *seeds* up to 5 mm., each with a colorless sac-like aril. The roughening of the seed is due to conical warts arranged in longitudinal rows. Cross sections show that these warts make up the bulk of the outer dark-colored spermoderm and that within the latter is the thin inner spermoderm with raphe and the round endosperm with thin, flat but broad cotyledons extending through the center.

MICROSCOPIC STRUCTURE.—Griebel[1] notes the chief microscopic characters of the pericarp and seed.

Pericarp (Fig. 270).—Cross sections show four layers: (1) *epicarp* (*epi*) of cuticularized cells and occasional stomata; (2) *hypoderm* of parenchyma cells, some with an oxalate rosette (*cr*); (3) *mesocarp* (*mes*) consisting of thin-walled, rounded cells, latex tubes (*l*), and fibrovascular bundles (*v*); and (4) *endocarp* of thin-walled cells rounding out into the fruit cavity.

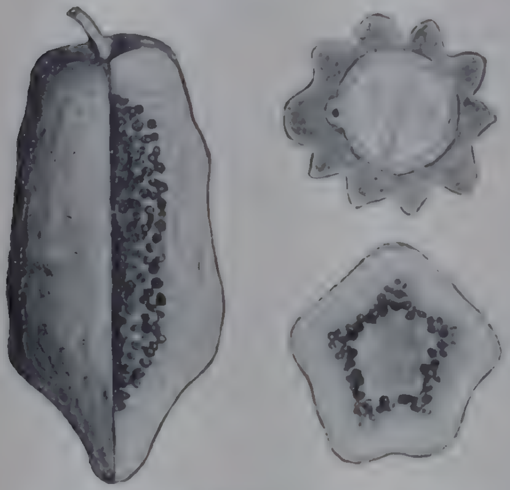

FIG. 269.—Papaya. Fruit cut to show rind and dark seeds. ×¼. Right, above: Seed in cross section showing thin aril, dark wrinkled outer spermoderm, inner spermoderm with raphe, and fleshy endosperm bisected by thin cotyledons. ×4. (A.L.W.)

In surface view the *epidermal cells* are polygonal, sometimes approaching square and often showing division into daughter cells.

Chlorophyl grains occur in all the outer parts.

Aril (Fig. 271, *A*).—Cross sections show an *outer epiderm* with a cuticle and more or less collapsed, thin-walled cells forming the remaining layers. In surface view the epidermal cells are rounded-polygonal. Fine granules staining yellow with iodine in potassium iodide are the only visible contents.

Spermoderm (Fig. 271, *S*).—Seven layers are differentiated: (1) *outer epiderm* (*aep*) of exceedingly thin-walled, colorless cells with radial, rod-like thickenings; (2) *brown spongy parenchyma* (p^1) with large cells and intercellular spaces; (3) *brown spongy parenchyma* (p^2) with small cells and intercellular spaces; (4) *crystal cells* (*cr*) conspicuously round in contour, each with a single crystal up to 35 μ in the inner portion; (5) a single layer of *longitudinally elongated fibers* (*f*) with thick walls; (6) *transversely elongated fibers* (*f*) in several rows; and (7) *inner epiderm* (*iep*) of isodiametric cells with faintly ribbed radial walls and dark brown contents.

Perisperm.—Not evident.

Endosperm (Fig. 271, *E*).—Typical *aleurone cells* form the bulky tissue. Large aleurone grains up to 30 μ, each containing one or more globoids, and fat are the visible contents.

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[1] Z. Unters. Lebensm. 1928, 55, 89.

Embryo.—The rounded cells of the *cotyledon* (Fig. 271, *C*) contain small aleurone grains and fat.

CHIEF STRUCTURAL CHARACTERS.—Fruit melon-like, large. Aril colorless, sac-like; seeds bur-like, brown. Spermoderm brown, warty; endosperm globular, bulky; cotyledons flattened, thin, central.

Hypoderm with oxalate rosettes; mesocarp with numerous latex tubes. Aril starch-free. Outer epiderm of spermoderm thin-walled, with radial rod-like thickenings; bulk of spermoderm of brown spongy parenchyma; crystal cells with single crystals and thick-walled longitudinally elongated fibers conspicuous. Aleurone grains of endosperm large, up to 30 μ, of cotyledons small.

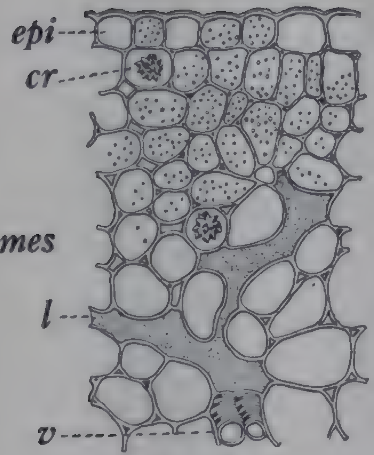

FIG. 270.

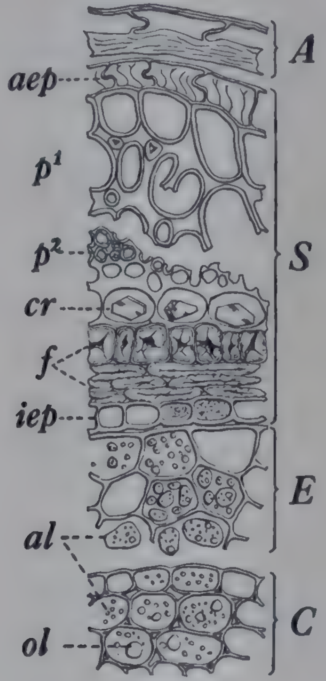

FIG. 271.

FIG. 270.—Papaya. Outer pericarp in cross section. *epi* epicarp; *cr* crystal rosette of hypoderm; *mes* mesocarp with *l* latex tube and *v* vessels. × 160. (K.B.W.)

FIG. 271.—Papaya. Seed in cross section. *A* aril. *S* spermoderm: *aep* outer epiderm, p^1, p^2 spongy parenchyma, *cr* crystal cells, *f* crossing fibers, *iep* inner epiderm. *E* endosperm and *C* cotyledon with *al* aleurone grains and *ol* oil drops. × 160. (K.B.W.)

CHEMICAL COMPOSITION.—The fruit flesh has been analyzed by Pratt and Del Rosario,[1] Thompson,[2] and Adriano.[3] See next page.

Changes in Composition during Ripening.—Thompson[4] tabulates results on the fruit flesh of the papaya at ripeness and at seven dates

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[1] Philippine J. Sci. 1913, **8**, 59.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

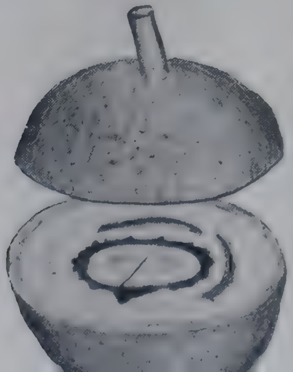
[3] Philippine Agr. 1925, **14**, 57.

[4] Loc cit.

MICROSCOPIC STRUCTURE. Pericarp (F
number five: (1) *epicarp* much torn and unrecognizable at maturity; (2) *hypoderm* (*hy*) of small cells; (3) *outer mesocarp* (*mes*[1]) of porous-walled cells, branching oleoresin ducts (*ol*[1]), and fibro-vascular bundles containing vessels with several spiral strands; (4) *inner mesocarp* (*mes*[2]) of large, thin-walled pulp cells, radially elongated in the inner part, also oleoresin ducts; and (5) *endocarp* consisting of crossing bundles of fibers (f^1, f^2) with lumen broader than the walls, also small brown exceedingly thin-walled parenchyma cells (*br*), one or more thick, adjoining the mesocarp and surrounding the fiber bundles.

Between the outer and inner mesocarp are two or more rows of flattened, thin-walled cells (*x*) through which separation of the rind takes place easily.

Spermoderm.—While there is no separation of endocarp from spermoderm, the latter is doubtless represented by the inner zone of collapsed thin-walled brown cells.



T THE CACTUS FAMILY

(*Cactaceæ*)

species are eaten in tropical and sub-tropical nt being grouped as prickly pears and cane fig and tunas (species of *Opuntia*) and pitayas *naireocereus*, and *Cereus*). The prickly pears acti round-jointed.

CROSCOPIC STRUCTURE.—In all the of consolidated receptacle and pericarp con- *eeds*, the whole being comparable with the , bristles, and spines occur in spiral rows on e cacti, whereas fleshy scales characterize the *ocereus*. The seeds of the prickly pears and coating (endocarp) which is not found on the

CROSCOPIC STRUCTURE.—Both groups ss fruit flesh excepting the numerous oxalate ably sharp points. The hairs, barbed bristles, s of the prickly pears are characteristic in in the perisperm, at least of the prickly pears, e endosperm and cotyledons.

EMICAL COMPOSITION.—The percentages g) and *acid* vary greatly. A low sugar content a high acid content.

PRICKLY PEAR

Opuntia spp.

Sp. Tuna. It. Fico d'India.
Ger. Indische Feige.

The Indian fig (*O. ficus-indica* Mill.), which is usually spineless, and the tuna (*O. Tuna* Mill.), which is always spiny, together with their hybrids are the most widely distributed forms. The fruit of the tuna is somewhat smaller than the Indian fig, but there is no sharp distinction, and both names, as well as prickly pear, are indiscriminately applied to cultivated varieties.

The prickly pear is the chief article of diet among the peons in many sections of the arid regions. Several species were early introduced into the Mediterranean region and thence into the tropics and sub-tropics throughout the world where they have run wild and often, as in Australia, become serious pests. In the Italian Quarters of New York and some other cities large quantities brought in from Sicily are sold on street stands and push carts. The fruit is delicious, but the barbed bristles of needle sharpness, even when reduced to a minimum by breeding, necessitate careful handling, and the hard stones are objectionable. The fruit is dried and is also used for making tuna-honey, sweetmeats, and fermented liquors.

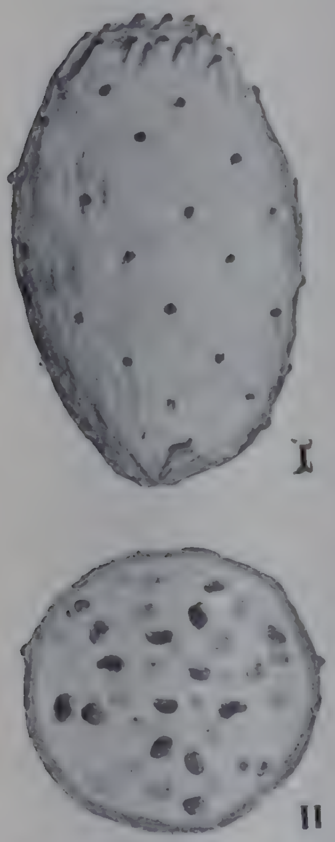


Fig. 272.—Prickly Pear. I whole; II cross section. × ½. (A.L.W.)

MACROSCOPIC STRUCTURE.—The fruit described herewith was from the Italian section of New York City.

The *flowers* occur singly on the areoles. The lower part consists of modified stem, which, as in the apple, may be regarded as receptacle consolidated with the ovary. On this are borne the numerous stamens and the spreading sepals and petals which fall away from the fruit after fertilization.

The one-celled *fruit* (Fig. 272) is urn-shaped, varying in color from yellow to red or purple, depending on the species, variety, or degree of ripeness, with areoles spirally arranged. These latter at the apex are on pronounced conical elevations and much crowded. A cross section shows a rind several millimeters broad about the gelatinous pulp in which are embedded the numerous "seeds," also several indistinct parietal placentæ.

Gray[1] in former editions states, under the head *Opuntia*, that the *seeds* are flat and margined, covered with a white bony arillus, but in the last revision is less specific. Our histological studies indicate that these so-called seeds are seeds consolidated with the bony lining of endocarp pockets and are more properly designated *stones*. They are kidney-shaped and contain a curved embryo, also sometimes another embryo of small size, surrounded by endosperm, perisperm, and spermoderm.

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[1] Manual of Botany of the Northern United States.

MICROSCOPIC STRUCTURE.—Montemartini[1] studied both the fruit and the seed.

Pericarp.—The consolidated receptacle and pericarp consists of (1) *epicarp* (Fig. 273, *epi*) of polygonal cells with thick outer and thin radial walls, large stomata, and on the areoles soft hairs and stiff bristles; (2) *hypoderm* (*hy*) of thick, porous-walled cells, three to five deep, often in the outer layer containing large crystal rosettes with blunt points (cr^1); (3) *mesocarp* (*mes*) of large cells often containing chlorophyl grains, smaller cells each containing a crystal with long acute points (cr^2) and fibro-vascular bundles of narrow elements; and (4) *endocarp* (Fig. 274, *end*) of tangentially elongated stone cells six

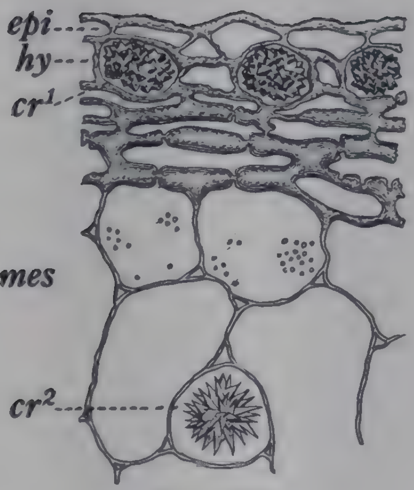

FIG. 273.

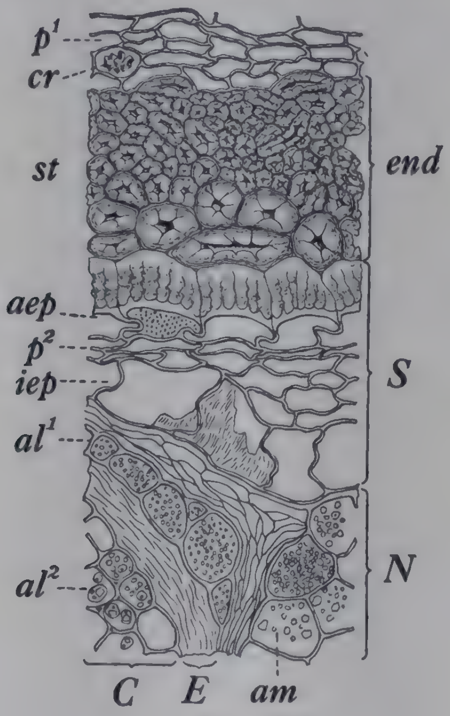

FIG. 274.

FIG. 273.—Prickly Pear. Outer fruit tissues in cross section. *epi* epicarp; *hy* hypoderm with cr^1 crystal rosettes; *mes* mesocarp with chlorophyl grains and cr^2 sharp pointed crystal rosettes. × 160. (K.B.W.)

FIG. 274.—Prickly Pear. Stone in cross section. Pericarp: p^1 inner mesocarp with *cr* crystal rosette, *end* endocarp of *st* stone cells. *S* spermoderm: *aep* outer epiderm, p^2 compressed parenchyma, *iep* reticulated inner epiderm. *N* perisperm with *am* starch grains. *E* endosperm and *C* cotyledon with al^1 and al^2 aleurone grains. × 160. (K.B.W.)

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[1] Atti Ist. botan. Univ. Pavia, 1897, 5, 59.

to ten deep except on the edges of the seed where there are twice as many, the inner cells being largest.

The soft *hairs* (Fig. 275, V, VI) of the areoles are thin-walled, mostly 1 to 2 mm. long, and jointed, the cells increasing in breadth from the base toward the tip. Of special interest are the barbed *bristles* or emergences which vary greatly in width and the nature of the barbs. The stiff penetrating bristles have downwardly directed barbs (I and II), whereas some of the limp, narrow forms have only upwardly directed (III) and others both upwardly and downwardly directed barbs (IV).

As in the stone of the peach and raspberry, the mesocarp tissues join on to the endocarp stone cells without break, whereas at the juncture of the latter and the outer epiderm of the spermoderm both tissues appear to end, although pressed closely together. Further evidence is furnished by the absence of the stone cell tissue in the pitaya and the obvious epidermal nature of a layer in this fruit, corresponding closely in structure to the one here so designated. Seeds of the *Cactaceæ* are described as "black"; the black layer of the prickly pear lies beneath the stone cell layer.

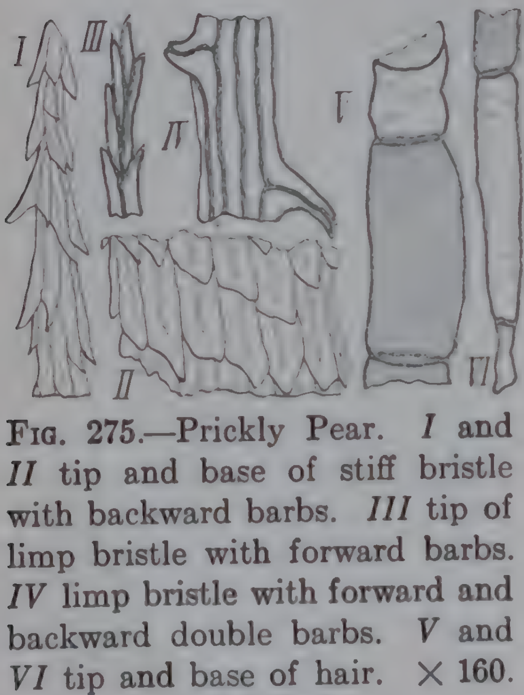

Fig. 275.—Prickly Pear. *I* and *II* tip and base of stiff bristle with backward barbs. *III* tip of limp bristle with forward barbs. *IV* limp bristle with forward and backward double barbs. *V* and *VI* tip and base of hair. × 160. (A.L.W.)

Spermoderm (Fig. 274, *S*).—Three layers are differentiated: (1) *outer epiderm* (*aep*) of dark brown cells, with enormously thickened and apparently porous outer walls, containing granules; (2) brown *parenchyma* (p^2) through which runs the raphe; and (3) *inner epiderm* (*iep*) of large, dark brown cells with very thin, delicately reticulated walls.

Perisperm (Fig. 274, *N*).—Over most of the seed, this is represented by compressed cells and a thick outer cuticle, but between the tips of the cotyledons and the radicle there is in addition a considerable tissue of thin-walled, well-defined cells containing starch grains (*am*) usually 1 to 2 μ but sometimes reaching 8 μ in diameter.

Endosperm (Fig. 274, *E*).—Excepting a single layer containing small aleurone grains (al^1), the cells are compressed.

Embryo.—The more or less isodiametric cells of the cotyledon (Fig. 274, *C*) and radicle contain aleurone grains (al^2) up to more than 10 μ, each with one or more globoids and often a well-defined crystalloid.

Chief Structural Characters.—Fruit with areoles bearing hairs, bristles, and spines. Seeds enclosed in endocarp forming stones; embryo curved, embedded in perisperm and thin endosperm.

Epicarp hairs weak, broad at tip, bristles variously barbed; hypoderm with thick porous walls; crystal rosettes large, in hypoderm with blunt points, in mesocarp with sharp points; endocarp of dense stone cell tissue. Outer epiderm of spermoderm with much-thickened outer wall; inner epiderm delicately reticulated. Perisperm containing starch grains. Endosperm and embryo containing aleurone grains.

CHEMICAL COMPOSITION.—Lima [1] furnishes data on the parts of prickly pears (*O. Ficus-indica*) grown in Italy. The average weights of the immature and ripe pears were 125 and 112 grams respectively.

Composition of Prickly Pear (Lima)

	In whole fruit	Water	Protein	Protein, pure	Fat	Sugars, total	Sugars by hydrolysis	Ash
	%	%	%	%	%	%	%	%
Immature:								
Skin	39	86.19	0.63	0.40	0.08	0.13	5.55	0.15
Flesh	58	92.95	0.50	0.37	0.07	5.02	0.17	0.25
Stones	3	33.37	2.17	8.24	8.53	....	....	1.29
Ripe:								
Skin	33	88.24	1.01	0.32	0.05	0.16	4.12	0.40
Flesh	63	90.21	1.54	1.10	trace	5.60	2.69	0.33
Stones	3	36.16	1.23	9.87	8.19	....	....	1.45

Hare and Griffiths [2] give in separate tables analyses of the fruit flesh (pared fruit exclusive of stones) of thick- and thin-rind species or varieties, grouped according to the place of growth. The Texas thick-rind samples were all from *O. lindheimeri* Engelm.; the Mexican thick-rind samples from *O. streptacantha* Lem., *O. leucotricha* DC., *O. larreyi* Weber, and *O. robusta* Wendl. The American (U. S.) thin-rind samples were from *O. macrocentra* Engelm. et Bigel, *O. engelmannii cycloides* Engelm. et Bigel, *O. lævis* (?) Coulter, *O. lindheimeri* Engelm., and *O. phæacantha* Engelm.; the Mexican thin-rind samples, so far as determined, from *O. engelmannii cuija* G. et H., *O. streptacantha* Lem., and *D. leucotricha* DC. The tabulated summary herewith shows that the Mexican fruit is much less acid and somewhat more saccharine than the American.

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[1] Staz. sper. agr. ital. 1895, **28**, 805.

[2] Loc. cit.

Composition of Prickly Pear Flesh (Hare and Griffiths)

(Number of samples in parentheses)

	Weight	Flesh in fruit	Solids	Protein, pure	Amides	Acids as malic	Sugars, total	Sucrose	Alcohol ppt.	Ash*	Ash, alk.†
	g.	%	%	%	%	%	%	%	%	%	cc.
Thick-rind:											
Texas (5)...											
Min.....	21	23.5	5.33	0.06‡	0.14‡	0.96	0.00	0.00	0.39‡	0.17§	4§
Max.....	72	33.3	7.80	0.06‡	0.14‡	2.95	7.18	0.41	0.39‡	0.42§	40§
Aver.....	**35**	**28.4**	**6.74**	**0.06‡**	**0.14‡**	**1.68**	**2.94**	**0.14**	**0.39‡**	**0.30§**	**22§**
Mexico (26).											
Min......	24	21.8	7.66	0.05	0.06	0.03	7.08	0.00	0.15	0.02	4
Max.....	164	62.6	14.08	0.17	0.84	0.44	11.70	1.58	0.39	0.74	66
Aver.....	**71**	**42.3**	**11.84**	**0.11**	**0.28**	**0.11**	**9.53**	**0.22**	**0.24**	**0.36**	**23**
Thin-rind:											
U. S. (6)											
Min......	14	59.7	10.11§	....	....	0.30	3.35	0.00	....	0.50§	57§
Max.....	44	83.6	12.08§	....	....	2.16	9.03	2.60	....	0.59§	77§
Aver.....	**26**	**74.1**	**11.10§**	....	....	**1.02**	**5.61**	**1.09**	....	**0.55§**	**67§**
Mexico (11).											
Min......	21	78.2	7.02	0.09	0.05	0.06	4.18	0.00	....	0.18	12
Max.....	94	93.0	14.14	0.31	0.61	0.95	9.19	1.19	....	1.20	89
Aver.....	**49**	**83.9**	**10.87**	**0.16**	**0.24**	**0.34**	**7.66**	**0.13**	....	**0.76**	**45**

* In soluble solids. † Cc. *N*/10 acid per 100 grams of fruit. ‡ 1 sample. § 2 samples.

The waste portion of Hare and Griffith's samples consisted chiefly of rind, even in the case of the thin-rind varieties. In the thick-rind varieties, the percentage of stones ranged from 1.52 to 9.68, in the thin-rind varieties from 2.95 to 15.84 per cent. In Mexican varieties, both thick- and thin-rind, the stones for the most part formed less than 5 per cent of the fruit.

Analyses of the rind from 12 thick-rind varieties where the amount of peelings was large (29.4 to 58.9 per cent) and somewhat palatable showed: solids 6.71 to 14.96, soluble solids 4.37 to 12.81, true protein 0.10 to 0.13, amides 0.04 to 0.18, acid as malic 0.18 to 1.31, total sugar 2.76 to 7.74, sucrose 0.00 to 2.06, alcohol precipitate 0.23 to 1.80, and ash in soluble solids 0.25 to 1.38 per cent with alkalinity of 30 to 116 cc. N/10 acid per 100 grams of fruit.

Separate analyses of the stones and pulp or the whole fruit and pulp are reported by Griffiths and Hare [1] as shown on the next page.

Changes in Composition during Ripening.—Analyses made by Hare and Griffiths [2] show that during a month's growth and ripening the sugars increased from 6.87 to 11.92 per cent and the acid decreased from 0.28 to 0.04 per cent.

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[1] Loc. cit.

[2] New Mexico Agr. Exp. Sta. Rep. 1909, p. 18.

Composition of Prickly Pear Flesh and Stones (Griffiths and Hare)

	Part of fruit	Water	Protein	Fat	N-f. ext.	Fiber	Ash
		%	%	%	%	%	%
O. phæacantha..........	Stones	7.26	6.07	11.41	23.18	50.33	1.75
	Flesh	92.50	0.20	0.07	4.63	0.51	2.09
O. spinosior............	Whole	77.74	1.74	1.11	11.50	4.94	2.97
	Flesh	83.04	0.55	0.24	11.74	1.33	3.10
Echinocactus Wislizeni...	Stones	8.59	10.92	15.46	36.59	25.37	3.09
	Flesh	94.14	0.63	0.06	3.05	1.16	0.96
O. fulgida..............	Whole	82.84	0.63	0.51	11.63	1.69	2.70
	Flesh	87.17	0.47	0.27	9.66	0.91	1.58

Fatty Oil of Stones.—As separated from *tuna blanca de huerta* of Mexico in the preparation of jelly bricks (panes or quesos) the stones, according to an analysis by Lomanitz,[1] contained water 7.68, oil 10.89, and ash 2.96. From the stones by extraction with petroleum ether was obtained a greenish yellow, semi-drying oil with the following values: specific gravity 15.5°/15.5° 0.9294, refractive index at 40° C. 1.4676, saponification number 189.5, iodine number 116.3, Reichert-Meissl number 2.8, Hehner number 93.8, ester number 186.5, and acid number 3.09.

Carbohydrates.—Hare [2] found that the juice of the ripe fruit contained 1.57 per cent of *pentosans*, also *levulose* and *dextrose* but only traces of *galactan*. The author gave special attention to the *mucilage* present in the immature fruit which disappears on ripening. This mucilage, separated by precipitation with alcohol from a 2 per cent solution, contained galactan 15, pentosan 31, and ash 12 per cent. Although the mucilage could not be separated completely from cell wall fragments, starch, and oxalate crystals, a dilute solution containing 1.5 per cent of soluble solids, filtered through silk, was optically inactive both before and after acid hydrolysis. By digestion for several hours with 1.25 per cent sulphuric acid, a sugar similar to arabinose was formed.

Colors.—A glucosidal pigment suitable for coloring food was obtained by Hare,[3] after removal of the mucilage and gum with alcohol, by precipitation from the filtrate with acetone. The lead salt of the pigment was precipitated by lead acetate from which in turn it was liberated

[1] J. Ind. Eng. Chem. 1920, **12**, 1175.

[2] New Mexico Agr. Exp. Sta. 1911, Bul. **80**; Biochem. Bul. 1912, **2**, 173.

[3] Loc. cit.

by sulphuric acid. The color yielded on hydrolysis a sugar with the properties of dextrose.

Mineral Constituents.—Results on the individual constituents in the parts of the fruit by Lima,[1] corresponding to the percentages of crude ash given in his table above, appear in the table which follows:

Composition of Ash of Parts of Prickly Pear (Lima)

(Results in percentages of fresh fruit)

	K_2O	Na_2O	CaO	MgO	Fe_2O_3*	P_2O_5	SO_3	SiO_2	CO_2
	%	%	%	%	%	%	%	%	%
Immature:									
Skin	0.002	0.002	0.016	0.017	0.003	0.003	0.002	0.003	0.064
Pulp	0.017	0.110	0.013	0.008	0.005	0.027	0.002	0.0003	0.021
Stones	0.049	0.236	0.058	0.149	0.156	0.049	0.073	0.220	0.160
Ripe:									
Skin	0.012	0.003	0.126	0.076	0.005	0.004	0.007	0.001	0.097
Pulp	0.080	0.020	0.025	0.038	0.079	0.032	0.017	0.0001	0.035
Stones	0.186	0.481	0.449	0.207	0.196	0.004	0.002	.....	0.021

* Includes Al_2O_3.

PITAYA

Hylocereus undatus Brit. et Rose.

Popenoe[2] states that the name pitaya is applied to several species belonging to the genera *Hylocereus*, *Lemaireocereus*, and *Cereus*, but that the most widely cultivated is the species named above which is often incorrectly known as *Cereus triangularis*.

The description which follows is of a specimen of fruit furnished by Prof. H. T. Cowles, of Mayaguéz, P.R.

MACROSCOPIC STRUCTURE.—The pitaya differs from the prickly pear in that it has a triangular *stem*, is night-blooming, has more or less tubular *flowers*, has red *fruits* covered with large fleshy scales, and is without a hard endocarp tissue about each *seed*.

MICROSCOPIC STRUCTURE.—While the structure in most respects corresponds with that of the prickly pear, there are several radical differences. First, *hairs*, *bristles*, and *spines* are absent; second, the *crystal rosettes* are much smaller; third, an *endocarp* of stone cell tissues is entirely lacking; fourth, the perisperm is less bulky.

Chief Structural Characters.—As noted above.

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[1] Loc. cit.

[2] Manual Trop. Subtrop. Fruits, New York, 1920, p. 451.

FRUITS OF THE POMEGRANATE FAMILY

(*Punicaceæ*)

ONLY one genus, *Punica*, and only two species, one of which is the pomegranate, belong in this family.

The juice contained in the outer epiderm of the spermoderm is remarkable in that the acid is largely or entirely citric.

POMEGRANATE

Punica Granatum L.

Fr. Grenade. Sp. Granada. It. Melagrana. Ger. Granatapfel.

Originating in Persia, the pomegranate has been cultivated since prehistoric times and has figured conspicuously in oriental art and literature. De Candolle strongly refutes the common belief that the tree is indigenous to north Africa, although there can be no doubt that it has been cultivated there and throughout the Mediterranean region since early times.

Scientifically the species is remarkable because the edible part is the outer epiderm of the spermoderm, the cells of which are enormously developed, and further because the seeds are borne on both axial and parietal placentæ.

True grenadine is prepared from the juice of the pomegranate, but commercial bottled grenadine is commonly an artificial preparation made from tartaric acid, vanilla, sugar, and coloring matter, the flavor of the vanilla being strangely modified by the acid.

The astringent rind of the fruit and the bark of the root are used in medicine. Certain varieties are cultivated as ornamentals.

MACROSCOPIC STRUCTURE.—Flowers, fruit, and seeds are various shades of red. Sepals and petals, normally six each, also numerous stamens, are borne above the ovary which normally is three-celled below with axial placentæ and six-celled above with parietal placentæ, but has only one style and stigma. Both series of placentæ begin as axial, but owing to the faster growth of the peripheral layers of the consolidated receptacle and pericarp the upper series change to parietal and this arrangement persists in the fruit.

The *fruit* (Fig. 276), which varies greatly in size, is crowned by the stiff calyx lobes and the dried-up stamens and style. The rind is thin and leathery, the placental tissue more bulky, soft, and spongy. Numerous angular seeds are crowded into the remaining space. Because of the enormous size of the cells of the outer epiderm, cell walls are largely eliminated so that the light-colored, inner, stony part of the seed is clearly visible through the wine-red sap. The stone, that is the seed deprived of the succulent tissue, is about the size of a grape seed, angular at the sides, pointed at the base, and rounded at the top. It consists of the inner hard layers of the seed, the thin perisperm and endosperm, and the bulky embryo with rolled-up and often folded cotyledons.

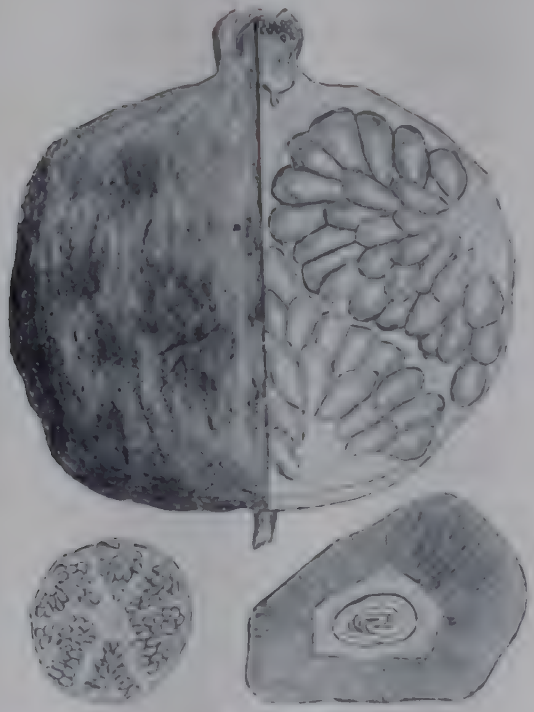

FIG. 276.

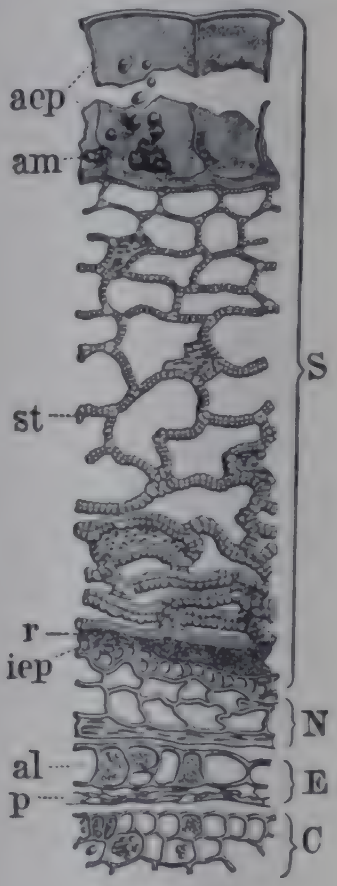

FIG. 277.

FIG. 276.—Pomegranate. Fruit with quarter removed, × ½, and in cross section, × ⅙. Below, right, seed in cross section showing outer spermoderm with dark red juice, inner stone-like spermoderm, and coiled cotyledons. × 4. (A.L.W.)
FIG. 277.—Pomegranate. Seed in cross section. *S* spermoderm: *aep* outer epiderm with *am* starch grains, *st* sclerenchyma cells, *r* spirally reticulated cells, *iep* inner epiderm. *N* perisperm. *E* endosperm: *al* aleurone cells, *p* compressed parenchyma. *C* cotyledon. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE.—The histological studies of the pomegranate have been largely confined to the rind of the fruit and the bark of the root, which are of pharmaceutical importance.

Pericarp.—The rind, consisting strictly of receptacle and pericarp, is made up of (1) *epicarp* of isodiametric, thick-walled cells with beaded radial walls and thick cuticle; (2) *meoscarp* of more or less loose parenchymatous ground tissue with stone cells of various forms, occurring singly and in groups, and fibro-vascular bundles; and (3) *endocarp* of isodiametric or tangentially elongated cells with beaded, somewhat thickened, wavy walls.

In the dissepiments the ground tissue cells are often beaded and sclerenchymatized.

Spermoderm (Fig. 277, *S*).—The tissues are in four layers of which the second shows marked transitions: (1) *outer epiderm* (*aep*), of enormously high, prismatic cells, often exceeding 2 mm., with thickened inner walls, containing wine-red sap, and in some cells starch grains (*am*); (2) *sclerenchyma* (*st*), varying from small thin-walled cells in the outer part to large thick-walled cells, and then to smaller thick-walled, flattened cells; (3) minute *spirally reticulated cells* (*r*), one or more thick, with brown walls; and (4) *inner epiderm* (*iep*) of longitudinally elongated, brown cells with thickened inner walls.

The *outer epiderm* is a remarkable example of robust cell development. If shown entire the cells would extend to about double the length of the printed page. Only a clear wine-colored sap is evident in the cells at full maturity, but when the sap is not fully colored a certain amount of transitory starch gives it a milky appearance. The *starch grains* are usually 5 to 8 μ in diameter, reaching in extreme cases 15 μ. They are isodiametric and occur singly, as rounded forms, or in small aggregates with truncated surfaces of contact.

Perisperm (Fig. 277, *N*).—This is represented by one or two rows of more or less well-defined cells and a structureless inner compressed tissue.

Endosperm (Fig. 277, *E*).—A single layer of aleurone cells (*al*) with finely granular contents and a compressed tissue (*p*) are evident in cross section.

Embryo.—The *cotyledons* (Fig. 277, *C*) and *radicle* are characterless with small aleurone grains forming the visible cell contents.

Chief Structural Characters.—Fruit with leathery outer walls. crowned by stiff floral parts; dissepiments thin; placentæ spongy. Seeds numerous, stone showing through transparent wine-colored, edible outer layer; perisperm and endosperm thin; cotyledons revolute.

Outer epiderm of spermoderm often over 2 mm. thick; second layer sclerenchymatous; third layer of minute spirally reticulated cells. Perisperm, endosperm, and embryo characterless, starch-free.

CHEMICAL COMPOSITION.—Parsons [1] analyzed the pulp, after separation of the stones, of a sour and a sweet variety grown in Georgia. Bornträger and Paris [2] separated 6 samples of the fruit weighing 189 to 380 grams into (1) husk and placentæ 28.4 to 41.8 per cent; (2)

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[1] Am. Chem. J. 1888, **10**, 487.

[2] Z. Unters. Nahr.-Genussm. 1898, **1**, 158.

whole seeds, including the juicy outer coat and the hard stones, 58.2 to 71.6 per cent; and (3) juice from the seeds 36.4 to 61.3 per cent, all calculated to the whole fruit, and analyzed the juice and the stones. Thompson[1] analyzed the pulp and stones together and the pulp alone.

COMPOSITION OF POMEGRANATE

	Solids, total	Solids, insol.	Protein	Fat	Citric acid	Malic acid	Sugars, reducing	Sucrose	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
Parsons:										
Pulp										
Sweet.	21.73	. . . . .	1.33	1.24	0.37	. . . .	11.61	1.04	2.63	0.76
Sour.	24.59	. . . . .	1.60	2.05	1.85	. . . .	10.40	0.26	2.83	0.54
B. and P.:										
Juice										
Min.*.	15.04†	. . . . .	1.04†	. . . .	0.37	0.08‡	7.81	0.00	. . . .	0.28†
Max.*.	15.04†	. . . . .	1.04†	. . . .	3.36	0.11‡	13.69	0.00	. . . .	0.28†
Aver.*.	**15.04†**	. . . . .	**1.04†**	. . . .	**1.38**	**0.10‡**	**11.09**	**0.00**	. . . .	**0.28†**
Stones.	64.98§	. . . . .	9.38	6.85	. . . .	. . . .	. . . . .	. . . .	24.41	1.54
Thompson:										
Pulp and stones	26.33	10.14	1.49	0.48	0.17‖	. . . .	12.21	0.00	5.30	0.59
Pulp.	17.52	1.98	0.53	0.30	0.20‖	. . . .	15.00	1.07	0.33	0.74

* Results in grams per 100 cc. † 1 sample. ‡ 3 samples. § Starch 12.64%. ‖ Acidity calculated as citric.

The fresh rind, according to Flaccomio,[2] contains: wax 0.8, resin 4.5, manitol 1.8, amorphous sugars 2.7, gum 3.2, inulin 1.0, mucilage 0.6, tannin 10.4, gallic acid 4.0, and malic acid, pectin, and calcium oxalate 4.0 per cent.

Acids.—Pratt, as reported by Bigelow and Dunbar,[3] found in the juice 4.52 per cent of acid calculated as *citric* by titration and the same amount by actual determination. Nelson,[4] by the ester distillation method, was unable to detect any acid other than citric.

Color.—In pomegranate juice Karrer and Widmer[5] identified *punicin* (pelargonidin diglucoside).

Minor Mineral Constituents. *Iron.*—Edible portion 11.7 mg. per kilo, fresh basis (Peterson and Elvehjem).[6]

Zinc.—Inner portion of fruit, 2.5 mg. per kilo, fresh basis (Bertrand and Benzon).[7]

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[1] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[2] Prog. terap. Sez. farm. 1929, **18**, 183.

[3] J. Ind. Eng. Chem. 1917, **9**, 762.

[4] J. Am. Chem. Soc. 1927, **49**, 1300.

[5] Helv. Chim. Acta. 1927, **10**, 67.

[6] J. Biol. Chem. 1928, **78**, 215.

[7] Bul. soc. hyg. aliment. 1928, **16**, 457.

FRUITS OF THE MYRTLE FAMILY

(*Myrtaceæ*)

Two genera yield succulent fruits, *Psidium* (guavas) and *Eugenia* (rose apple, jambolan, Surinam cherry, etc.). Clove fruit, produced by a species of *Eugenia*, and allspice, belonging to a related genus, *Pimenta*, are described under Spices in Volume III.

COMPARATIVE MACROSCOPIC STRUCTURE.—Characteristic of the *fruit* are the calyx teeth at the top and the stone cells of the pulp recognized on chewing. The guava has many seeds, species of *Eugenia* only one or two, in all cases without considerable endosperm. In guava and allspice the radicle is fleshy and the cotyledons minute; in eugenias, including clove fruit, the cotyledons are fleshy and the radicle minute.

COMPARATIVE MICROSCOPIC STRUCTURE.—*Volatile oil cavities* occur in the pericarp (strictly receptacle and pericarp) and cotyledons. *Chains of cells* characterize the mesocarp of cloves, rose apple, and macopa, while the cells of jambolan and allspice are normal parenchyma.

Bicollateral bundles are characteristic of the family, sieve tubes occurring both outside and inside the xylem.

GUAVA

Psidium Guajava L.

Fr. Goyave. Sp. Guayaba. It. Pera Indiana. Ger. Guajave.

The guavas are small tropical trees or shrubs, natives of the New World, yielding luscious, agreeably musty fruits eaten out of hand, preserved after removal of the seeds, and also used to a large extent for making guava jelly, a product of superior excellence known the world over.

In addition to common guava, with varieties formerly classified as species, Popenoe [1] describes the following less important species: strawberry guava (*P. Cattleianum* Sabine) with round purplish red fruit up to 4 cm. in diameter, a native of Brazil; Costa Rican guava (*P. Fried-*

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[1] Manual Trop. Subtrop. Fruits, New York, 1920, p. 272.

richsthalianum Ndz.) with yellow fruit, up to 6.5 cm. long; guisaro (*P. molle* Bertol.) with fruit smaller than the last, a native of Mexico and Central America; Brazilian guava (*P. guineense* Sw. = *P. Araca* Raddi) with greenish yellow fruit up to 4 cm.

MACROSCOPIC STRUCTURE.—The *flowers* are white, 2 to 2.5 cm. broad, with an urn-shaped consolidated receptacle and ovary crowned by a calyx with several lobes formed by splitting, four petals, and numerous stamens.

Fruits of the different varieties differ to such an extent in form (globular, oblong, pear-shaped) and size (up to 10 cm. long) as to have led earlier botanists to assign them specific names. Characteristic of all are the irregular calyx lobes (Fig. 278). The color of the fruit flesh is green, whitish, yellow, or pink. In the several (usually four) locules are numerous hard, buff, triangular or kidney-shaped *seeds*, 3 to 5 mm. long. The embryo of the anatropous seed is curved and consists largely of radicle, the cotyledons being minute.

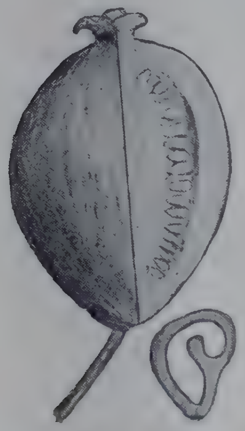

FIG. 278.

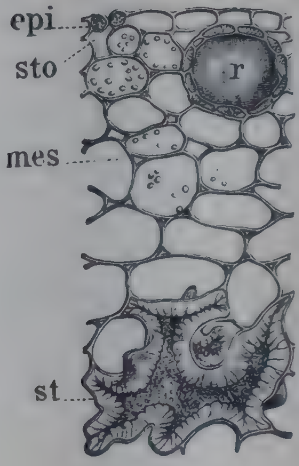

FIG. 279.

FIG. 278.—Guava. Fruit showing rind, central placenta, and seeds. × ½. Below, seed in longitudinal section showing horny spermoderm and curved embryo. × 2. (A.L.W.)

FIG. 279.—Guava. Outer pericarp in cross section. *epi* epicarp with *sto* stoma; *r* oleoresin cavity; *mes* mesocarp with *st* stone cell. × 160. (K.B.W.)

MICROSCOPIC STRUCTURE.—The **Pericarp** (Fig. 279) consists of (1) *epicarp* (*epi*) with moderate-sized, polygonal cells and occasional stomata (*sto*); (2) *hypoderm* with oleoresin cavities (*r*) up to 200 μ; (3) *mesocarp* (*mes*) of thin-walled parenchyma in which are numerous stone cells (*st*), occurring singly or more commonly in groups, and fibrovascular bundles; and (4) *endocarp* of thin-walled tissue.

Numerous *chlorophyl grains* are present in the outer tissues. The *stone cells*, which as in the pear and quince are evident on chewing, resemble in form more those of the olive and avocado, being much-branched and often grotesque.

Spermoderm.—Excepting the thin-walled *outer* and *inner epiderms* and a meager layer of additional thin-walled tissue below the former, the spermoderm is hard and made up of a dense mass of *stone cells* with, especially in the middle portion, thick walls and narrow lumens. Most of the stone cells are more or less transversely elongated; in some groups, however, they are longitudinally elongated.

About the feebly developed fibro-vascular bundles there is a small amount of parenchyma tissue.

Perisperm.—A thin compressed layer, several cells thick, is evident, especially on treatment with reagents.

Endosperm.—*Aleurone cells*, forming a single layer, represent the endosperm. The aleurone grains are minute.

Embryo.—Unlike the eugenias, the strongly developed radicle contains the bulk of the reserve material which is not starchy. Here the *aleurone* grains reach 22 μ, each with numerous globoids and some with what appears to be a crystalloid.

Chief Structural Characters.—Fruit variable in color, shape, and size; calyx lobes irregular; locules several. Seeds numerous, hard, triangular or kidney-shaped.

Mesocarp with oleoresin cavities and grotesque stone cells, often in groups. Spermoderm largely of elongated stone cells. Endosperm with single layer of aleurone cells. Embryo largely radicle containing aleurone grains up to 22 μ.

CHEMICAL COMPOSITION.—Some uncertainty exists as to what is meant by "edible portion" of guavas. Chace, Tolman, and Munson,[1] Pratt and Del Rosario,[2] Thompson,[3] Jaffa and Albro[4] and Adriano[5] appear to have used the same methods and include the seeds in the portion analyzed. Azadian[6] determined the sugars soluble in boiling water and the total ash. See table on page 806.

Composition of Guava Seeds.—A single analysis by Azadian[7] follows: water 10.30, protein 15.25, fat 14.30, tannin 1.38, glucose 0.10, starch 13.25, fiber 42.40, total ash 3.00, and soluble ash 2.69 per cent.

Fatty Oil of Seed.—Values of the oil extracted by a mixture of sol-

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Philippine J. Sci. 1913, **8**, 59.

[3] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

[4] Ann. Rep. Calif. Avocado Ass. 1917, p. 85.

[5] Philippine Agr. 1925, **14**, 57.

[6] Ann. fals. 1922, **15**, 405.

[7] Loc. cit.

Composition of Guava

	Samples	Solids, total	Solids, insol.	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
		%	%	%	%	%	%	%	%	%	cc.
C. T. and M.:	4										
Min.		19.61	11.75†	0.79‡	....	0.53	2.84†	0.16†	....	0.63	67†
Max.		22.14	15.21†	0.97‡	....	0.91	6.07†	0.91†	....	0.84	96†
Aver.		**21.32**	**12.94†**	**0.88‡**	....	**0.77**	**4.49†**	**0.45†**	....	**0.69**	**77†**
P. and Del R.	1	24.2	16.0	1.38	....	0.42	3.34	3.99	....	0.71	80
Thompson:											
Common	3										
Min.		15.43	7.27	1.13	0.35	0.37	5.73	0.55	4.42	0.53	..
Max.		18.75	8.99	1.53	0.52	0.64	6.61	2.53	5.10	0.68	..
Aver.		**17.32**	**8.00**	**1.39**	**0.43**	**0.51**	**6.04**	**1.28**	**4.66**	**0.62**	..
Strawberry	3										
Min.		18.27	7.36	1.04‡	0.42	1.00	2.32	2.05	3.87	0.64	..
Max.		23.75	14.47	1.84‡	0.79	1.67	3.64	6.37	9.38	0.76	..
Aver.		**20.70**	**10.60**	**1.44‡**	**0.59**	**1.23**	**2.79**	**3.91**	**6.46**	**0.71**	..
J. and A.:											
Lemon	1	16.00	.....	0.76	0.95	....	....	....	5.57	0.67	..
Strawberry	1	20.58	.....	0.88	0.80	....	....	....	6.58	0.77	..
Adriano	1	18.35	.....	0.96	0.07	....	....	....	6.84	0.73	..
Azadian	1	.....	.....	....	....	....	3.65§	4.60§	....	0.84	..

* Cc. $N/10$ acid per 100 grams fruit. † 3 samples. ‡ 2 samples. § Soluble in boiling water.

vents from 5 samples of seeds, reported by Azadian,[1] are given in the following table:

	Sp. gr. 15° C.	Ref. index 40° C.	Sapon. No.	Iodine No.	Reichert-Meissl No.	Polenske No.	Acid No.	Volatile oil
								%
Min.	0.9124	1.4587	190.0	127.9	0.20	0.20	0.34	0.03
Max.	0.9306	1.4700	216.0	134.5	0.38	0.30	0.70	0.27
Aver.	**0.9243**	**1.4632**	**197.1**	**131.1**	**0.26**	**0.25**	**0.55**	**0.25**

Kafuku, Hata, and Fujikawa[2] report results on specific gravity, refractive index, and saponification number within the above limits but higher results on iodine number (140.7) and acid number (340).

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[3] found 2.72 per cent, dry basis, in the fruit.

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[1] Loc. cit.

[2] J. Chem. Soc. Japan 1934, 55, 375.

[3] Philippine Agr. 1932, 21, 53.

Mineral Constituents.—Chace[1] found 0.84 per cent of ash in the pulp and the percentages of constituents in the ash given below:

K_2O	CaO	MgO	P_2O_5	SO_3	SiO_2	Cl
% 55.00	% 2.48	% 1.64	% 8.29	% 3.58	% 1.13	% 5.33

ROSE APPLE

Eugenia Jambos L. = *Jambos vulgaris DC.* = *J. Jambos Mill.*
= *Caryophyllus Jambos* Stokes

Fr. Pomme-rose. Sp. Poma-rosa. Ger. Rosenapfel.

This East Indian species is valued for its beautiful foliage and flowers as well as its fragrant fruits. It is variously known in India and the Islands as gulab-jaman, jambos, jambo, jamrosade, etc. The fruit is used chiefly for jellies, preserves, and confectionery.

Another species, *E. malaccensis* L. (*Jambosa malaccensis* DC.), known as large-fruited rose apple or jambos, also, according to Popenoe, as ohia and Malay apple, and in the West Indies as Otaheite apple, belonging to the *Jambosa* section, is closely related to the rose apple and cloves. It is a native of the Malayan region.

Several Brazilian species, little known outside of South America, belonging to the *Eugenia* (proper) section, are described by Popenoe[2] and Hall.[3] Among these are the grumichama (*E. Dombeyi* Skeels = *E. braziliensis* Lam.), the pitanga or Surinam cherry (*E. uniflora* L. = *E. Michelii* Lam.), and uvalha (*E. Uvalha* Camb.).

The third section, *Syzygium*, is represented by the jambolan described hereinafter.

MACROSCOPIC STRUCTURE.—Among the characters of the *flowers* are the united receptacle and ovary, the four inconspicuous concave petals, and the numerous long bristling stamens obscuring the other parts. The *fruit* (Fig. 280) is green or yellow, plum-shaped, about 5 cm. long, surmounted by four fleshy calyx lobes. The single

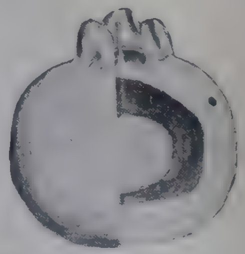

FIG. 280.—Rose Apple. Fruit with section removed showing three of four calyx lobes, style, stigma, and single seed. ×½. (A.L.W.)

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87, 29.

[2] Manual Trop. Subtrop. Fruits, New York, 1920, p. 305.

[3] Bailey: Stand. Cycl. Hort., New York, 1922.

cavity contains one or two round, polyembryonic seeds, up to 1.5 cm. in diameter, made up largely of the bulky cotyledons.

MICROSCOPIC STRUCTURE.—No literature on the histology of the fruits of species of *Eugenia* has been brought to our attention.

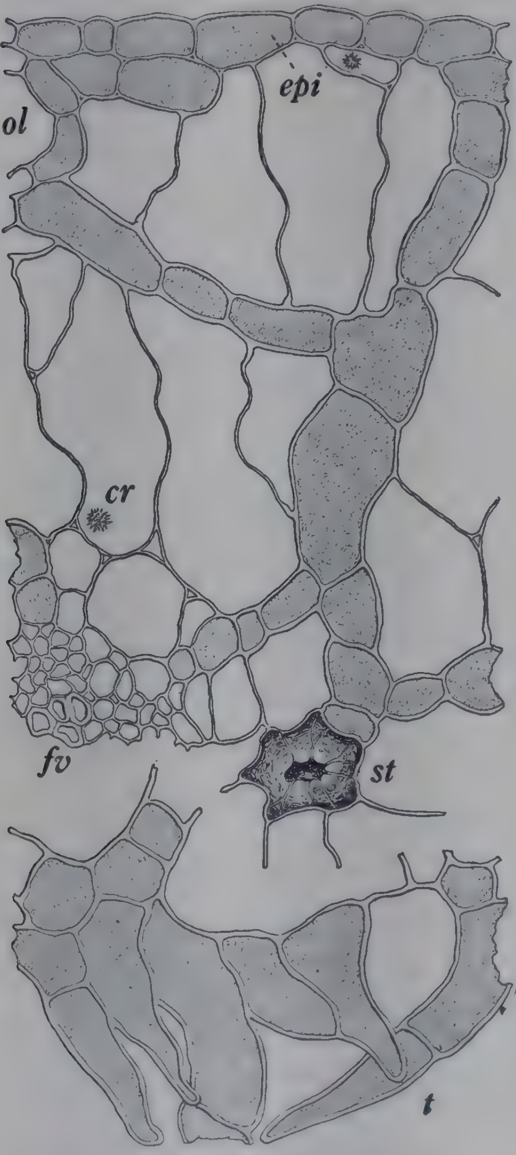

Fig. 281.

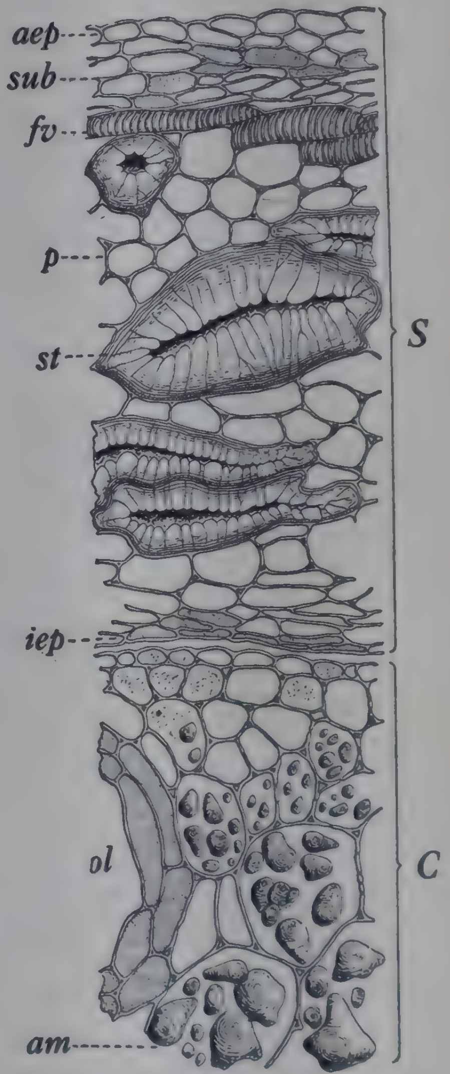

Fig. 282.

Fig. 281.—Rose Apple. Pericarp in cross section. *epi* epicarp; *ol* oleoresin cavity; chains of small cells (dark); large cells (colorless); *cr* crystal rosette; *fv* fibro-vascular bundle; *st* stone cell; *t* endocarp hairs. × 160. (K.B.W.)

Fig. 282.—Rose Apple. Seed in cross section. *S* spermoderm: *aep* outer epiderm, *sub* subepiderm, *p* ground tissue with *fv* fibro-vascular bundle and *st* stone cells, *iep* inner epiderm. *C* cotyledon: *ol* volatile oil cavity, *am* starch grains. × 160. (K.B.W.)

The **Pericarp** (Fig. 281) consists of (1) *epicarp* (*epi*) of polygonal cells interspersed with stomata which are few except on the calyx lobes where they are numerous; (2) *oleoresin cavities* (*ol*), up to more than 200 μ in diameter, forming an interrupted layer; (3) *mesocarp* made up of chains of small cells forming a network with large cells in the meshes, fibro-vascular bundles (*fv*), and colorless, isodiametric or somewhat longitudinally elongated stone cells (*st*), occurring singly or less often in small groups; and (4) *endocarp* with numerous unicellular or jointed blunt-pointed hairs (*t*) extending into the fruit cavity.

The *chains of cells* and the *endocarp hairs* contain brownish contents, at least in formaldehyde material, thus distinguishing them sharply from the *oleoresin cavities* and the *large cells* which are colorless and thinner-walled. These latter contain occasional *oxalate rosettes* (*cr*).

Spermoderm (Fig. 282, *S*).—Cross sections show the characterless, rather small-celled *outer epiderm* (*aep*), *subepiderm* (*sub*), and *inner epiderm* (*iep*). Between the last two named is a bulky *ground tissue* (*p*) of somewhat larger cells in which are embedded exceptionally large, tangentially elongated *stone cells* (*st*) of more or less irregular form, and in the outer portion the raphe bundle.

Embryo (Fig. 282).—Almost the entire bulk consists of the fleshy cotyledons (*C*). In cross section these, like the pericarp, show an interrupted layer of *oleoresin cavities* (*ol*) beneath the *outer epiderm.* Between these, as well as underlying them, the cells are indistinctly beaded and contain numerous, more or less pear-shaped starch grains (*am*), up to 45 μ long, with excentric hilum in the large end. Similar starch grains occur in the cotyledons of mother of cloves, jambolan, and doubtless other species of the genus.

Chief Structural Characters.—Fruit yellow or green, plum-like, 5 cm.; calyx lobes four, conspicuous, fleshy; locules one. Seeds one or two, round; embryo bulky, largely cotyledons.

Pericarp and cotyledons with oleoresin cavities; pericarp and spermoderm with stone cells, exceptionally large in latter; mesocarp ground tissue of chains of cells forming network about large cells; endocarp with numerous blunt-pointed hairs. Cotyledons containing pear-shaped starch grains up to 45 μ, with hilum in large end.

CHEMICAL COMPOSITION.—Tabulated below are the only available data on the composition of *Eugenia* fruits, secured by Pratt and Del Rosario[1] and by Thompson.[2] The samples analyzed include, in addition to rose apple (*E. Jambos*), the jambolan (*E. jambolana*), the macopa (*E. javanica*), the ohia or mountain apple (*E. malaccensis*), and the pitanga or Surinam cherry (*E. michelii*). The acidity is given tentatively as citric for the reason that this has been shown to be the acid of the guava belonging to the same group. Pratt and Del Rosario give the acid of one species examined by them as citric and of another as malic without explanation.

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[1] Philippine J. Sci. 1913, 8, 59.

[2] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

Composition of Flesh of Eugenia Fruits

	Flesh in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as citric	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
Rose apple:											
Hawaiian..	63	15.85	3.70	0.79	0.19	0.06	11.26	0.47	0.98	0.30	..
Jambolan:											
Philippine†	75	19.2	3.5	0.81	....	0.91	12.70	0.00	....	0.70	96
Hawaiian..	56	15.63	3.54	0.62	0.52	1.20	12.99	0.00	0.16	0.29	..
Macopa:											
Philippine‡	90	8.6	1.9	0.50	....	0.15	6.56	0.00	....	0.27	26
Ohia:											
Hawaiian..	74	8.61	....	0.21	0.04	0.10	6.88	0.00	0.56	0.14	..
Pitanga:											
Hawaiian..	84	9.30	1.93	1.02	0.66	2.06	4.68	1.38	0.34	0.34	..

* Cc. *N*/10 acid per 100 grams pulp. † Weight 4 grams. ‡ Weight 30 grams.

JAMBOLAN

Eugenia jambolana Lam. = *Syzygium jambolana* DC.
= *S. Cumini* Skeels.

Fr. Jamelongue. Sp. Lumboy.

This fruit, like the rose apple, is a native of the East Indies. Pratt and Del Rosario [1] state that in the Philippines it is known as *duhat* and is eaten in large quantities by the natives, especially the children, and is made into jelly equal in color and flavor to that of guava.

MACROSCOPIC STRUCTURE.—Unlike those of the rose apple, the petals are united.

The oval *fruit* is dark purple, up to 2.5 cm. long, with a low circular rim at the top but without calyx lobes. It resembles externally a ripe olive. The single fruit cavity contains a single somewhat oblong *seed*, closely united with the pericarp. The embryo consists largely of two bulky cotyledons, one arranged above the other in the longer axis of the fruit.

MICROSCOPIC STRUCTURE.—The pericarp (strictly united receptacle and pericarp) differs from that of the rose apple in that the contents of the *epicarp* are purple, the ground tissue of the *mesocarp* is made up of uniform cells without chains, the occasional stone cells are smaller but more elongated, and an *endocarp* with hairs is not differentiated, the inner pericarp being merged with the outer spermoderm.

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[1] Philippine J. Sci. 1913, 8, 59.

Spermoderm.—Although there is no sharp demarcation between this and the pericarp, it seems probable that the very narrow, but greatly elongated, fiber-like *stone cells* present in the inner tissues belong with the spermoderm. In the tissues immediately outside of these stone cells occurs what appears to be the *raphe bundle.* Fiber-like stone cells found outside of the latter may belong either to the pericarp or the spermoderm.

Embryo.—The *oleoresin cavities, mesophyl cells,* and *starch grains* of the cotyledons are like those of the rose apple.

Chief Structural Characters.—Fruit purple, about half as long as rose apple, calyx lobes absent, pericarp grown to the single seed.

Chains of mesocarp cells and hairy endocarp absent; mesocarp stone cells smaller and more elongated than in rose apple. Spermoderm stone cells fiber-like. Embryo much like that of rose apple.

CHEMICAL COMPOSITION.—See Rose Apple.

MACOPA

Eugenia javanica Lam.

This Malayan species is grown in the Philippines, but Pratt and Del Rosario[1] state that, although it is one of the most attractive fruits in the market, the pulp is tasteless and fluffy.

MACROSCOPIC STRUCTURE.—The turbinate pink *fruit,* with incurving and sunken calyx lobes, is about 4 cm. in diameter. As illustrated by the authors named above, the *seed* is similar in size to that of the rose apple but in the two samples kindly furnished by Miss Maria Orosa of the Philippine Bureau of Science, the seeds were abortive.

MICROSCOPIC STRUCTURE. Pericarp.—The *outer mesocarp* consists of large uniform pulp cells with oleoresin cavities immediately beneath the epicarp and occasional stone cells like those in the rose apple. The *inner mesocarp* consists of chains of small cells separated by intercellular cavities and ending in *endocarp hairs.* Only in the region of the attachment of the seeds is a continuous endocarp evident, the cells there being thin-walled and tangentially elongated.

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[1] Philippine J. Sci. 1913, 8, 59.

Chief Structural Characters.—Fruit turbinate, pink, 4 cm.; calyx lobes sunken, incurved.

Outer mesocarp pulp cells uniform, forming a close tissue; oleoresin cavities and stone cells as in rose apple; inner mesocarp of string-like, more or less free chains of small cells ending in endocarp hairs.

CHEMICAL COMPOSITION.—See Rose Apple.

FRUITS OF THE DOGWOOD FAMILY

(*Cornaceæ*)

Several species of the dogwood family bear edible fruits, but only one, the cornel cherry, is here considered.

CORNEL CHERRY

Cornus mas L.

Fr. Cornouille. Sp. Cornejo. It. Corniolo. Ger. Kornelkirsche.

The fruit of this species, which is much larger than that of our native dogwoods, is much prized in Europe where it is native.

MACROSCOPIC STRUCTURE.—The small yellow *flowers* are borne in umbels. The *fruit* is bright red, oblong, about 2 cm. long, with the remains of the style in a depression at the tip. A juicy fruit flesh, about 2 mm. thick, covers an elliptical, rough or furrowed *stone* with two locules and one or two cylindrical *seeds*, each with bulky endosperm and flat, thin cotyledons.

MICROSCOPIC STRUCTURE.—Examination of the fruit of *Cornus florida* L. corroborates in the main Griebel's findings[1] on the European species.

Pericarp.—This is made up of: (1) *epicarp* of thick-walled, porous cells with occasional large stomata and T-shaped, thick-walled hairs or their scars; (2) *mesocarp* of colorless pulp cells, tannin cells (Inklusen), delicate bundles, and occasional crystals; and (3) *endocarp* of a mass of thick-walled, colorless stone cells, many with single crystals.

Spermoderm.—Characterless.

Endosperm.—The bulky tissue consists of small *aleurone cells* rich in fat.

Embryo.—The small cells of the *cotyledons* contain protein and fat.

CHEMICAL COMPOSITION.—The range in composition of the flesh, as given by Hotter,[2] appears below:

Composition of Cornel Cherry (Hotter)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%
Min....	18.0	4.4	13.8	2.9	8.1	4.1	4.1	0.08	0.73
Max....	21.2	4.4	15.8	2.9	9.1	4.5	4.7	0.09	0.74

* As invert. † Phosphoric acid 0.05 to 0.08%.

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[1] Moeller: Mikros. Nahr.-Genussm., Berlin, 3 Aufl. 1928, p. 261.

[2] Z. landw. Versuchsw. 1906, 9, 747.

FRUITS OF THE HEATH FAMILY

(*Ericaceæ*)

All the woody plants of this family yielding the small edible "berries" herewith described grow in temperate or sub-arctic regions.

COMPARATIVE MACROSCOPIC STRUCTURE.—The cranberry and foxberry have four calyx teeth and four locules; the blueberries and huckleberry have five calyx teeth and ten locules. In all, the *seeds* are anatropous with a thin spermoderm, bulky endosperm, and small axial embryo.

COMPARATIVE MICROSCOPIC STRUCTURE.—Stone cells occur in the *mesocarp* of the huckleberry; they form a dense *endocarp* in the huckleberry and a loose endocarp in the blueberries, but are absent in the cranberries. The outer epiderm of the *spermoderm* of the cranberries has tertiary gelatinous thickenings. The *endosperm* of all the species contains aleurone grains but no starch.

COMPARATIVE CHEMICAL COMPOSITION.—Representative of this family are the blueberry which is moderately saccharine but low in acid and the cranberry which is low in sugar but high in acid. In both cases citric is the chief acid but a certain amount of malic acid is also present.

HUCKLEBERRY

Gaylussacia resinosa Torr. et Gray

Of the several species of *Gaylussacia*, all natives of the Western Hemisphere, the common or black huckleberry (*G. resinosa*) is the most abundant and the fruit is gathered in large quantities for the market.

Of less importance is the blue tangleberry or dangleberry (*G. frondosa* Torr. et Gray) and the buckberry (*G. ursina* Torr. et Gray). In the central states the name "huckleberry" is applied to the tall swamp blueberry (*Vaccinium corymbosum*).

Like the blueberries, the huckleberry is much prized raw, as well as cooked in pies and puddings. It is also dried and canned. Huckleberry jam, although not commonly made, is of excellent flavor.

MACROSCOPIC STRUCTURE.—The *flower* resembles that of the blueberries but the ovary is ten-celled.

Also in its *fruit* (Fig. 283, I), the huckleberry externally resembles the blueberries, but is black without a bloom or rarely white. It bears a crown of five pointed calyx lobes surrounding a depression bearing the scar of the style. It is a ten-celled drupe, not a true berry, each so-called *seed* consisting of endocarp with a single seed within. The *stones* (II) surround the axis like the segments of an orange. Magnified they have a granular appearance (III) and in cross section (IV) are seen to be made up largely of woody endocarp enclosing the endosperm in the axis of which is the minute elongated embryo.

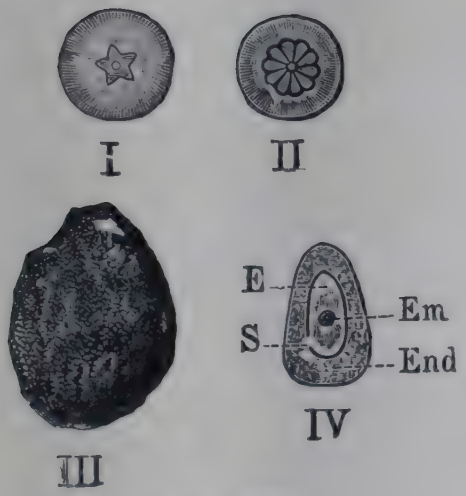

Fig. 283.

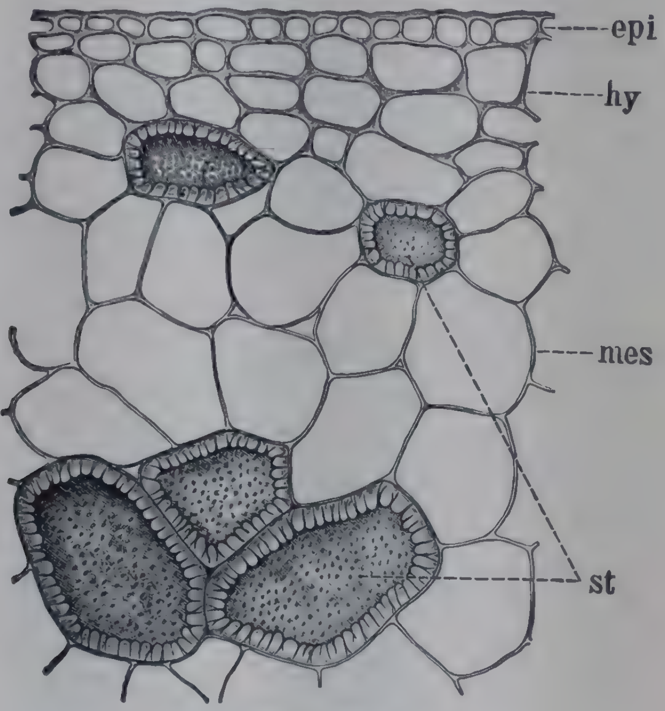

Fig. 284.

Fig. 283.—Huckleberry. I fruit seen from above. × 1. II fruit in cross section. × 1. III stone. × 8. IV stone in cross section: *End* endocarp, *S* spermoderm, *E* endosperm, *Em* embryo. × 8. (A.L.W.)

Fig. 284.—Huckleberry. Outer pericarp in cross section. *epi* epicarp; *hy* hypoderm; *mes* mesocarp; *st* stone cells. × 160. (A.L.W.)

MICROSCOPIC STRUCTURE.—Winton[1] finds the structure quite different from that of the blueberries or the cranberries.

Pericarp (Figs. 284 and 285).—The four layers are: (1) *epicarp* (*epi*) of polygonal cells with a thin cuticle, (2) *hypoderm* (*hy*) forming a double or triple layer of cells with somewhat thickened walls, (3) *mesocarp* (*mes*) of thin-walled parenchyma and stone cells (*st*), and (4) *endocarp* (*end*) of large stone cells and narrow sclerenchyma fibers (*lf*) longitudinally arranged.

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[1] Z. Unters. Nahr.-Genussm. 1902, 5, 785; Connecticut Agr. Exp. Sta. Rep. 1902, p. 288.

Being usually of large size with relatively broad lumen, the stone cells crush between the teeth in eating the fruit.

Spermoderm (Fig. 285, *S*; Fig. 286).—The cells of the single layer are large, wavy in outline, usually elongated, with reticulated walls formed by pores about 4 μ in diameter.

Perisperm (Fig. 285, *N*).—This is reduced to a narrow structureless coat.

Endosperm (Fig. 285, *E*).—The cells contain aleurone grains seldom reaching 10 μ.

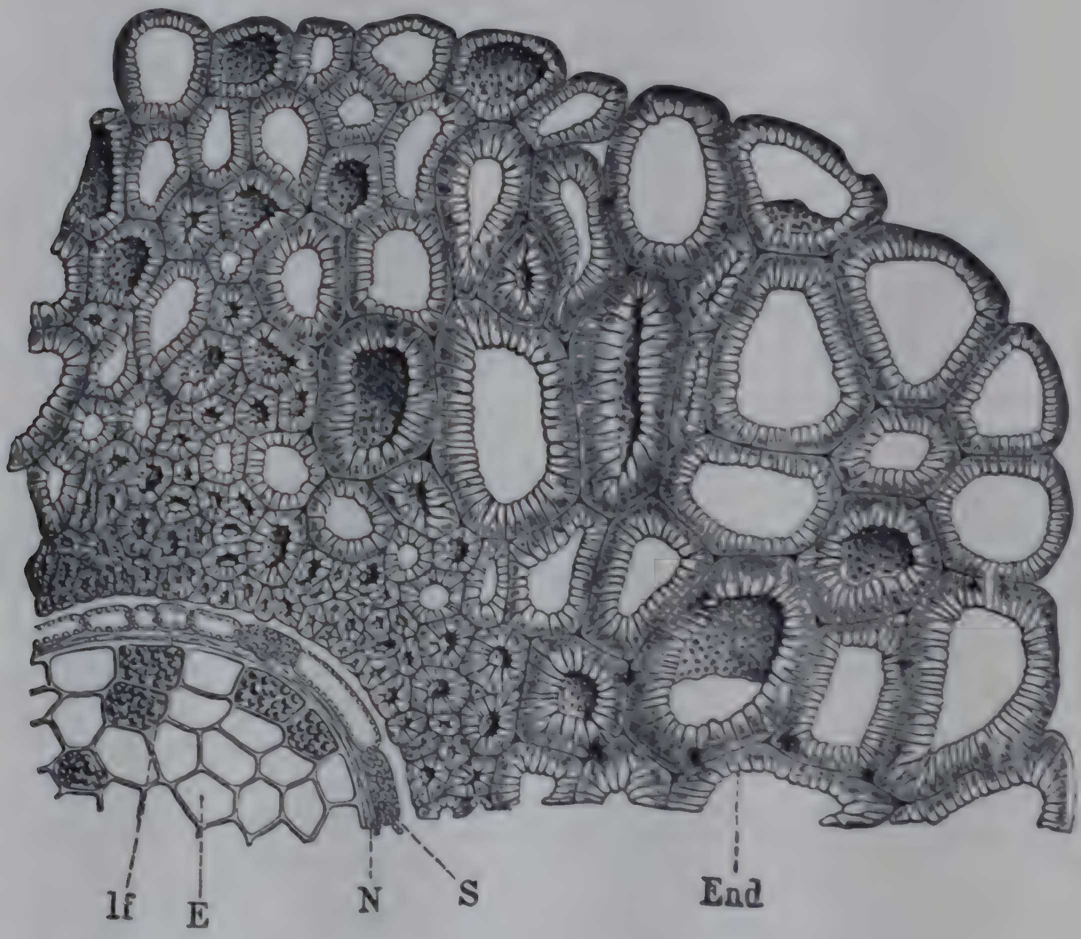

Fig. 285.—Huckleberry. Endocarp and seed in cross section. *End* endocarp with large stone cells and *lf* narrow fibers. *S* spermoderm. *N* perisperm. *E* endosperm. × 160. (A.L.W.)

Embryo.—Characterless.

Chief Structural Characters.—Fruit drupaceous, globular, black without bloom or rarely white; calyx teeth five; stones ten; endocarp woody and bulky. Seed small, consisting largely of endosperm with minute axial embryo.

Cuticle thin; mesocarp with stone cells; endocarp of stone cells and sclerenchyma fibers. Spermoderm of single layer of wavy-walled reticulated cells. Endosperm of aleurone cells.

CHEMICAL COMPOSITION.—A single analysis by Atwater and Bryant[1] showed the following percentages:

COMPOSITION OF HUCKLEBERRY

Water	Protein	Fat	N-f. ext.	Fiber	Ash
%	%	%	%	%	%
81.9	0.6	0.6	16.6	16.6	0.3

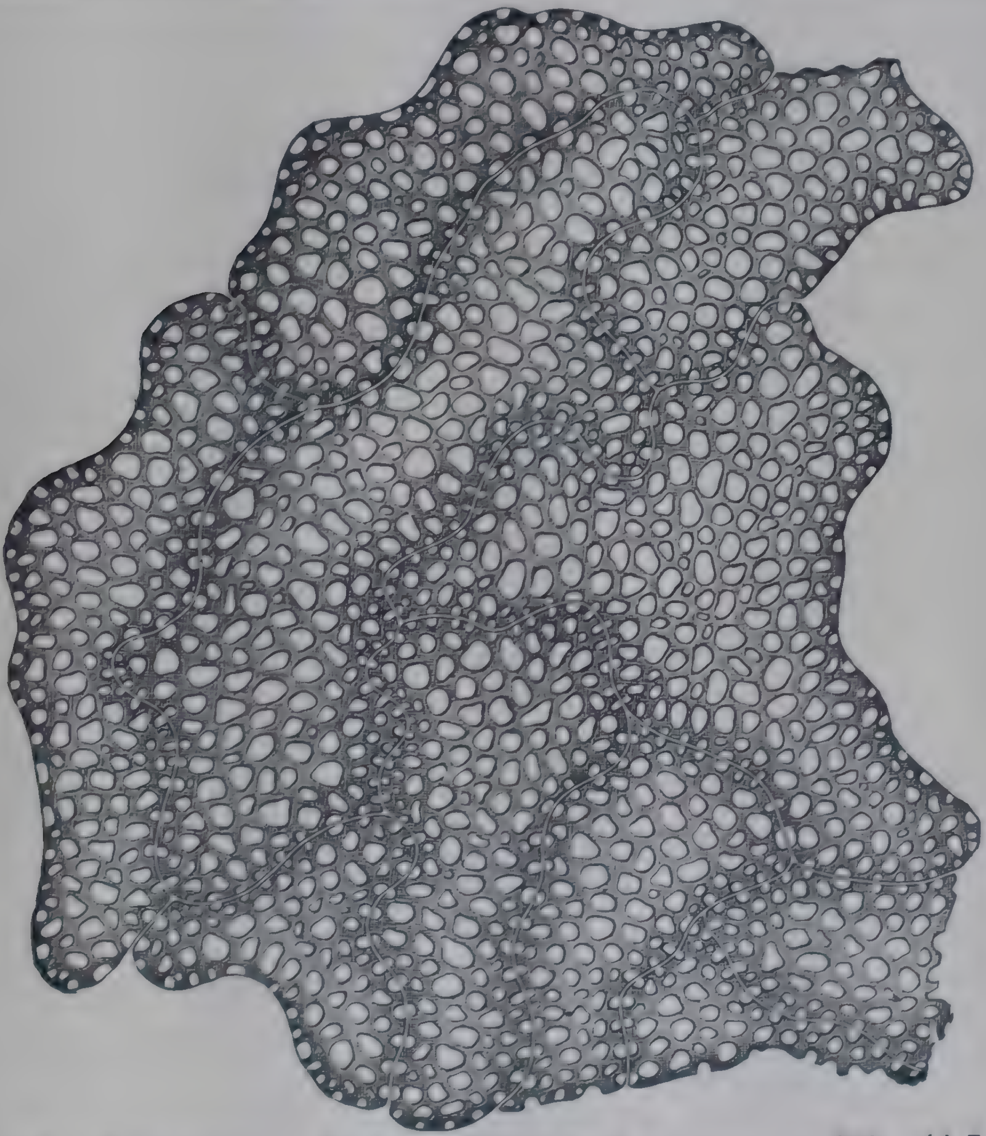

FIG. 286.—Huckleberry. Spermoderm in surface view. × 300. (A.L.W.)

Respiration.—Gore,[2] operating with 3 samples, noted a maximum evolution of 84 mg. of carbon dioxide per kilo per hour at 30.6° C. and a minimum of 7 mg. at 0.9° C.

Minor Mineral Constituents. *Iron.*—Berries 10 mg. per kilo, fresh basis (Häusermann quoted by Sherman).[3]

[1] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

[2] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1907, Bul. **185**.

BLUEBERRY

Vaccinium spp.

Ger. Heidelbeere.

Two low-growing shrubs, *V. pennsylvanicum* Lam., an early-fruiting species, and *V. vacillans* Kalm., a later-fruiting species, growing wild in the United States, supply the blueberries most commonly found on sale in the markets of the northern and eastern sections. Both yield sweet berries. Of the swamp blueberries the high-growing *V. corymbosum* L., the most important, yields a sweet berry, the low-growing *V. canadense* Kalm., a sour berry. Characteristic of the above species, as well as others of lesser importance, all belonging to the section *Cyanococcus*, is the blue-black berry with a bloom, although varieties of some, if not all, the species named, as well as the European whortleberry (*V. myrtillus* L.), have black berries. Albino forms of most of the species have been reported.

Munson[1] has devoted much attention to blueberries growing in Maine, both wild and cultivated. He states that in the southeastern part of Maine there are 150,000 acres of " blueberry barrens " yielding thousands of bushels of fruit, most of which goes to canneries. Coville, on soil corrected for acid deficiency by the addition of alum, has grown blueberries the size of grapes.

MACROSCOPIC STRUCTURE.—The calyx tube is adherent to the ovary, the five short calyx teeth persisting at the top of the fruit. The bell-shaped or cylindrical, white or pink corolla is also five-toothed but does not persist on ripening. Each of the five carpels is divided by a false partition which is an outgrowth of the midrib.

Berries of the common species are smooth, an exception being the hairy berry of *V. hirsutum* Buckl. Wild berries seldom reach 12 mm. in diameter but cultivated berries often exceed 2 cm. Each cell of the berry is lined by a thin but woody endocarp and contains numerous *seeds*. The embryo is minute, in the center of the bulky endosperm.

MICROSCOPIC STRUCTURE.—Müller and Blau[2] made an exhaustive study of the berries of *V. myrtillus* L.

Pericarp (including calyx tube).—The layers (Fig. 287) are (1) *epicarp* (*epi*) of beaded cells, containing a dark red solution; (2) *hypoderm* of collenchyma cells; (3) *mesocarp* of thin-walled sometimes sclerenchymatous parenchyma, with calcium oxalate rosettes (*cr*) in the inner portions, and fibro-vascular bundles (*fv*); and (4) *endocarp* (*sc*) consisting of a single layer of stone cells of various shapes and sizes in loose contact.

---

[1] Maine Agr. Exp. Sta. Rep. 1901, p. 113; also Bul. **76**.

[2] Pharm. Post 1902, **35**, 461.

Calyx Teeth (Fig. 287).—The outer *epiderm* (*ep*) is similar to that on the body of the berry (epicarp), but stomata with crescent-shaped accompanying cells are present.

Spermoderm.—The *outer epiderm* (Fig. 287, *aep*) is characterized by the great thickness of the inner walls and the inner portions of the side walls, also the numerous fine pores. From the corresponding cells of the cranberry, these are distinguished by the absence of mucilaginous thickening. The remainder of the spermoderm consists of thin-walled *parenchyma*, compressed in the innermost layers.

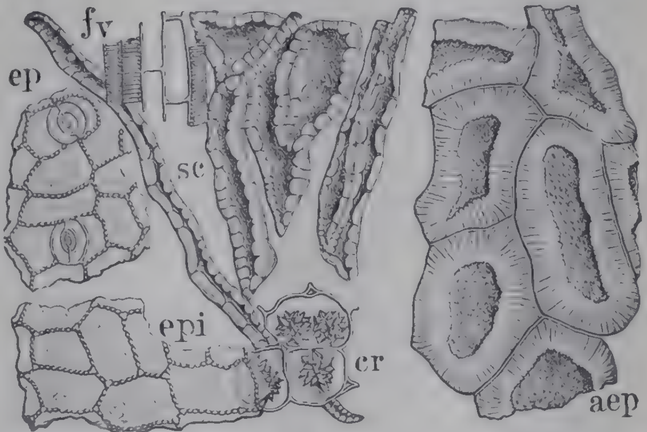

Fig. 287.—Tall Blueberry. Elements of fruit and seed in surface view. *epi* epicarp; *ep* outer epiderm of calyx tooth; *fv* fibro-vascular bundle and *cr* crystal cells of mesocarp; *sc* stone cells of endocarp; *aep* outer epiderm of spermoderm. × 160. (A.L.W.)

Endosperm and **Embryo.**—The *aleurone grains* vary up to 8 μ.

CHIEF STRUCTURAL CHARACTERS.—Berries globular, smooth (except in hairy blueberry), blue or black, often with bloom, crowned by five calyx teeth; carpels five but locules of fruit ten by false partitions; endocarp thin but woody. Seeds numerous; embryo minute in axis of bulky endosperm.

Epicarp with beaded (porous) walls; mesocarp of thin-walled cells, some sclerenchymatized but not, as in huckleberry, stone cells; endocarp of single layer of stone cells (not elongated cells as in cranberry or dense stone cell tissue as in huckleberry). Outer epiderm of spermoderm with inner walls and inner portion of radial walls thickened and porous but without mucilaginous thickening.

CHEMICAL COMPOSITION.—Of the meager literature, analyses of the European blueberry by Kulisch[1] and by Ystgaard[2] and a single analysis of the American blueberry by Atwater and Bryant[3] are reproduced on page 820.

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[1] Z. angew. Chem. 1894, p. 148.

[2] Tids. Norske Landbr. 1902, **9**, 125.

[3] U. S. Dept. Agr., Off. Exp. Sta. 1906, Bul. **28** rev.

Composition of Blueberry

	Samples	Solids	Protein	Fat	Acids as citric	Invert sugar	N-f. ext.	Pentosans	Fiber	Ash
		%	%	%	%	%	%	%	%	%
Kulisch....	1	13.40	0.83	....	1.13	6.28	.....	.....	......	0.32
Ystgaard:	4									
Min......		10.7*	....	....	0.55†	3.80	.....	0.6*	1.7*	0.06*
Max......		19.7*	....	....	1.00†	6.00	.....	1.4*	4.7*	0.15*
Aver.....		**15.3***	**0.50‡**	....	**0.93†**	**4.89**	.....	**0.98***	**3.19***	**0.11***
A. and B....	1	17.6	0.7	3.0	.....	....	13.5	.....	3.2	0.4

* 2 samples. † The acid as which the total acid is calculated is not stated. Two samples contained 0.38 to 0.45, aver. **0.42**% of malic acid and 0.02% of citric acid. ‡ 1 sample.

The range in composition of the pulp of 8 samples of Austrian blueberries reported by Hotter[1] follows: total solids 11.8 to 17.0, insoluble solids 2.8 to 4.7, extract 9.3 to 10.3, total sugar as invert 4.7 to 7.0, glucose 1.8 to 2.9, fructose 2.8 to 3.9, sucrose 0.1 to 0.6, acid as malic 0.9 to 1.2, tannin 0.13 to 0.31, total ash 0.27 to 0.37, and phosphoric acid 0.03 to 0.07 per cent.

Composition of Blueberry Juice.—The composition of the juice of European blueberries (species not given) is represented by 5 samples

Composition of Blueberry Juice

(Grams per 100 cc. juice)

	Samples	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Ash, total	Ash, alk.*
W. and S.:	5								
Min..........		1.027	7.06	0.09	0.87	3.92	0.09	0.23	24
Max..........		1.039	9.99	0.31	1.19	6.07	0.26	0.32	35
Aver.........		**1.033**	**8.62**	**0.23**	**0.95†**	**5.14**	**0.19**	**0.26**	**28**
Feder:									
V. myrtillus...	1	......	11.38	0.07	1.22	8.84	....	0.25	25
V. uliginosum.	1	......	10.27	0.09	1.04	8.20	....	0.19	19

* Cc. $N/10$ acid per 100 cc. juice. † Tannin, 1 sample 0.20%.

[1] Z. landw. Versuchsw. 1906, **9**, 747.

nalyzed by Windisch and Schmidt[1] and by 2 samples, each from a ifferent species, analyzed by Feder.[2] See table page 820.

In green, semi-ripe, and fully ripe Alsatian whortleberries, Guillaume nd Légo[3] found respectively: citric acid 0.135, 1.10, and 0.832 per cent; nalic acid 0.100, 0.040, and 0.044 per cent; reducing sugars 0.489, .51, and 2.24 per cent; sucrose 0.219, 0.20, 0.50 per cent; and total ugars 0.708, 1.71, and 2.74 per cent.

Composition of Blueberry Seeds.—Analysis by Diedrichs[4] of the lean air-dry seeds separated from European blueberries gave: water .75, protein 17.87, fat 31.00, nitrogen-free extract plus fiber 42.72, nd ash 1.66 per cent.

Fatty Oil of Seed.—Diedrichs[5] reports the following values of the rying oil obtained from the seeds: specific gravity at 15° C. 0.9331, efractive index at 25° C. 1.4782, saponification number 190.4, iodine umber 167.2, Reichert-Meissl number 0.66, Polenske number 0.30, ehner number 95.72, acid number 3.82, and hexabromides of linoleic nd linolenic acids 28.5 per cent.

Acids.—In European whortleberries, classed as huckleberry by Bigelow and Dunbar,[6] in their review of the literature on the organic cids of fruits, Nacken,[7] Kunz and Adam,[8] Jörgensen,[9] and Muttelet[10] ound *citric acid* together with more or less *malic*. Muttelet reports itric 0.76 per cent, malic 0.05 per cent, and tartaric none. Kaiser,[11] y the ester-hydrazide method, found in percentages of the total acids s follows: citric 72.38, malic 18.70, *succinic* 4.87, *lactic* 0.81, *oxalic* .16, *quinic* 2.68 (?), and unsaturated 0.40 per cent. Lebedev and Linquist[12] found that only half of the acid in *V. oxycoccus* is due to itric, the remainder consisting chiefly of quinic acid.

Nelson[13] reached the conclusion that the acids of the American lueberry are citric with a little *l*-malic.

Color.—Diemair and Lix[14] believe that the blue color obtained in the Plahl test with whortleberry juice is due to substances formed during the reaction that act on metallic ions. Phloroglucinol, furfurol, and protocatechuic acid were identified as products of the reaction.

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[1] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

[2] Pharm. Zentralh. 1912, **53**, 1321.

[3] Ann. fals. 1934, **26**, 12.

[4] Z. Unters. Nahr.-Genussm. 1912, **24**, 575.

[5] Loc. cit.

[6] J. Ind. Eng. Chem. 1917, **9**, 762.

[7] Forschungsber. Lebensm. 1895, **2**, 350.

[8] Z. Unters. Nahr.-Genussm. 1906, **12**, 670.

[9] Ibid. 1907, **13**, 241.

[10] Ann. fals. 1924, **17**, 454.

[11] Süddeut. Apoth. Ztg. 1925, **65**, 48.

[12] Z. Unters. Lebensm. 1933, **65**, 476.

[13] J. Am. Chem. Soc. 1927, **49**, 1300.

[14] Z. Unters. Lebensm. 1933, **66**, 540.

Mineral Constituents.—Kulisch [1] in a single analysis of the ash found:

K_2O	CaO	MgO	P_2O_5
% 32.9	% 8.7	% 5.9	% 12.8

Minor Mineral Constituents. *Iron.*—Berries 4.1 mg. per kilo, fresh basis (Peterson and Elvehjem).[2]

Manganese.—Berries 314.9 mg. per kilo, dry basis (Peterson and Skinner).[3]

Copper.—Berries 1.1 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

CRANBERRY

Vaccinium macrocarpon Ait.

The cranberry is a native American bog plant. Its cultivation began in the Cape Cod region but has extended to New Jersey, Wisconsin, and other states. The production is very large. Because of the presence of benzoic acid, this fruit, like the foxberry, keeps a long time, often drying up without decaying.

The fruit is exceedingly sour and not edible until cooked and sweetened. Both the sauce (jam) and jelly have a most pleasing flavor and are highly esteemed as adjuncts to roast turkey.

The small cranberry (*V. Oxycoccus* L.), a species indigenous to both the Old and New World, yields small fruits of no commercial importance.

MACROSCOPIC STRUCTURE (Fig. 288).—Like the foxberry but unlike the blueberries, the cranberry is four-merous. The four minute calyx teeth crown the ovary and persist on the fruit (I). The corolla is four-parted and deciduous. The *fruit* varies in form from globular to ovoid and in color from pink to maroon. Often the individuals reach 1.5 cm. in diameter. The fruit has four locules, each with several *seeds* on axial placentæ (II). When ripe not only the epicarp but also the inner fruit tissues are commonly colored red.

---

[1] Loc. cit.

[2] J. Biol. Chem. 1928, **78**, 215.

[3] J. Nutrition 1931, **4**, 419.

[4] J. Biol. Chem. 1929, **82**, 465.

The *seeds* (III, IV) are yellow, short-beaked, and anatropous. They have a firm spermoderm, a bulky endosperm, and a small axial embryo consisting largely of radicle.

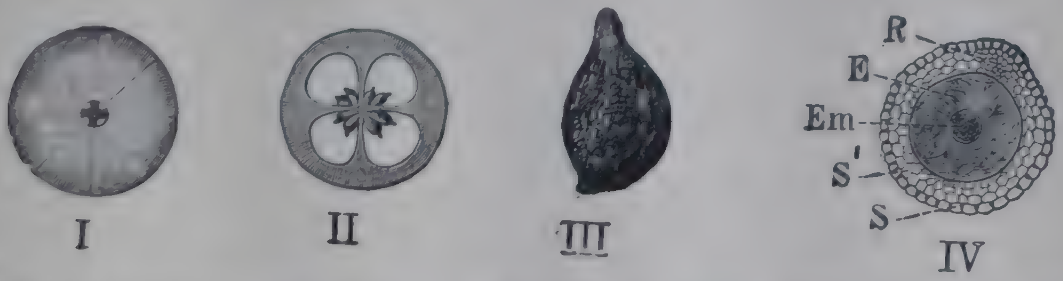

FIG. 288.—Cultivated Cranberry. I berry seen from above, × 1. II berry in cross section, × 1. III seed, × 8. IV seed in cross section: *S* outer and *S'* inner spermoderm, *R* raphe, *E* endosperm, *Em* embryo. × 15. (A.L.W.)

MICROSCOPIC STRUCTURE.—Winton,[1] also Griebel,[2] studied this fruit and the foxberry.

Pericarp.—In both the cranberry and foxberry there are four tissues: (1) *epicarp* (Fig. 289) of polygonal cells with a strongly developed cuticle but no stomata; (2) *hypoderm* (Fig. 289) of polygonal cells larger than those of the epicarp, forming a single layer; (3) *mesocarp* of isodiametric ground tissue cells, mostly of considerable size (up to

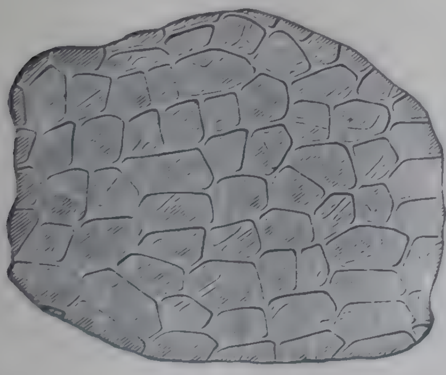

FIG. 289.

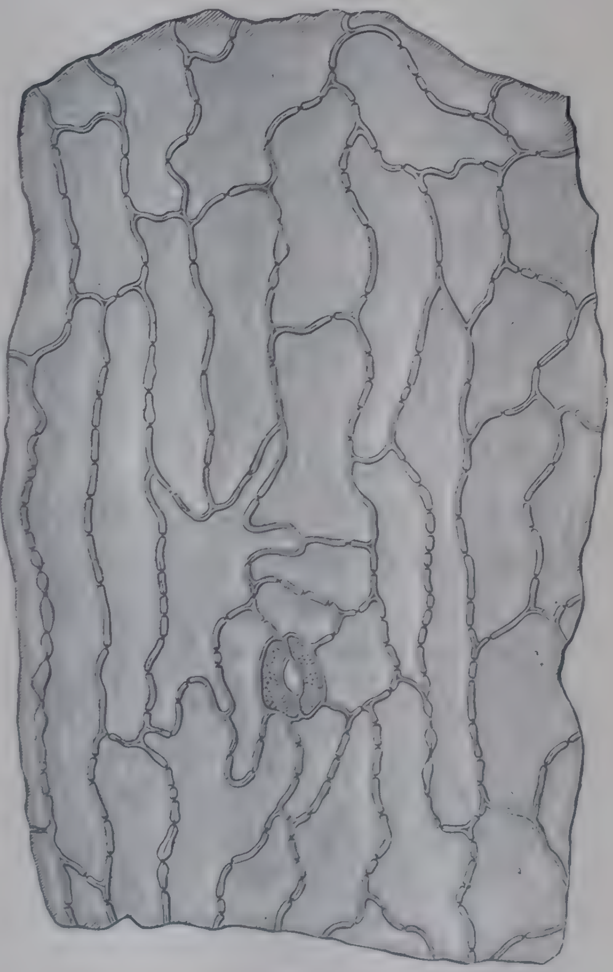

FIG. 290.

FIG. 289.—Cultivated Cranberry. Epicarp and hypoderm in surface view. ×160. (A.L.W.)

FIG. 290.—Cultivated Cranberry. Endocarp with stoma in surface view. ×160. (A.L.W.)

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[1] Z. Unters. Nahr.-Genussm. 1902, **5**, 785.

[2] Ibid. 1924, **48**, 228.

200 μ); and (4) *endocarp* (Fig. 290) of large, irregular, porous-walled cells, mostly longitudinally elongated (often up to 350 μ), and well-formed stomata.

Spermoderm.—Two forms of tissues are present: (1) *outer epiderm* (Fig. 291, *ep*; Fig. 292) of large, longitudinally elongated cells with thick, porous secondary thickening on the inner walls and inner ends of radial walls and in addition mucilaginous tertiary thickening on the radial walls; and (2) *inner layers* (Fig. 291, *m*) of large, somewhat thick-walled porous cells, often collapsed with no marked differentiation of an inner epiderm.

The *outer epiderm* is remarkable alike in cross section and in surface view. Treated with chlorzinc iodine, the secondary walls stain yellow, the swollen mucilaginous tertiary walls blue. Surface mounts show that the pores are transversely elongated.

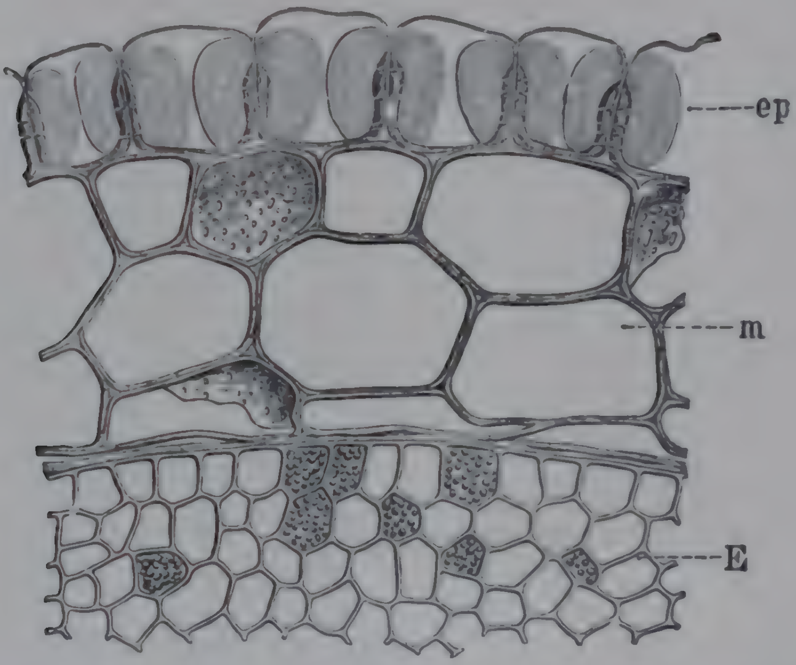

Fig. 291.—Cultivated Cranberry. Seed in cross section. Spermoderm: *ep* outer epiderm, *m* inner layers. *E* endosperm. × 160. (A.L.W.)

Endosperm (Fig. 291, *E*).—Isodiametric *aleurone cells* form the entire tissue. The aleurone grains are small.

Embryo.—The small thin-walled cells are not noteworthy.

Chief Structural Characters.—Fruit globular or ovoid, various shades of red, up to 1.5 cm.; calyx teeth and locules four. Seeds several in each locule, beaked; endosperm bulky; embryo central, minute.

Epicarp and hypoderm of polygonal cells; endocarp of large elongated porous cells and stomata. Outer epiderm of spermoderm with secondary sclerenchyma thickening on inner and radial walls, also tertiary mucilaginous thickening on radial walls. Endosperm of aleurone cells.

CHEMICAL COMPOSITION.—Goessmann[1] reports 2 analyses as follows: solids 10.71 and 10.11, protein 0.00 and 0.10, ash 0.00 and 0.18, and in the juice reducing sugar 1.35 and 1.70, sucrose 0 and 0, and acid as citric (recalculated from malic) 2.34 and 2.53 per cent.

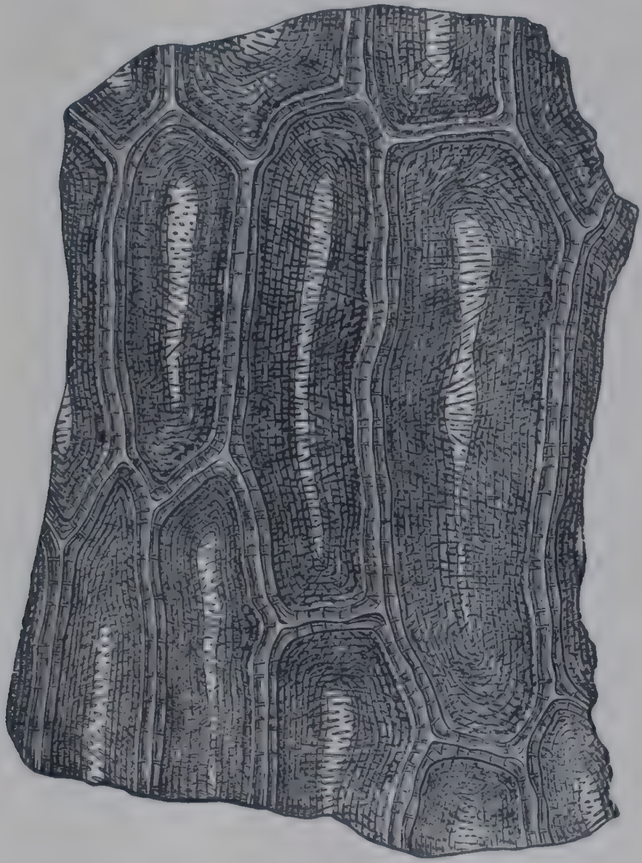

FIG. 292.—Cultivated Cranberry. Outer epiderm of spermoderm in surface view. × 160. (A.L.W.)

Morse and Jones[2] determined the proximate food constituents in 3 varieties with results as shown below:

COMPOSITION OF CRANBERRIES (MORSE AND JONES)

	Solids	Protein	Fat	N-f. ext.	Fiber	Ash
	%	%	%	%	%	%
Howes	12.23	0.35	0.97	9.25	1.51	0.15
McFarlin	11.26	0.35	0.57	9.00	1.18	0.16
Centennial	12.84	0.28	0.51	10.73	1.15	0.17

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[1] J. Am. Chem. Soc. 1879, **1**, 423.

[2] Massachusetts Agr. Exp. Sta. 1920, Bul. **198**, 75.

Morse[1] determined solids, acid, and sugar, in cranberries grown in three states, with results summarized in the following table:

	Varieties	Samples	Solids	Acids as citric	Sugar, total
			%	%	%
Massachusetts: aver.	43	87	12.36	2.30	4.13
New Jersey: aver.	13	13	12.03	2.35	3.74
Wisconsin: aver.	12	16	11.63	2.41	3.54
All three states:					
Min.	..	..	10.58	1.87	2.45
Max.	..	..	13.60	2.71	5.66
Aver.	..	..	12.22	2.32	4.00

Changes in Composition during Ripening.—When the fruit is left on the vines, Morse[2] found that during 1926 the total sugar of the variety Early Black increased from 1.98 per cent on August 31 to 3.74 per cent on September 23 and of the variety Howes from 1.63 per cent on August 31 to 4.51 per cent on October 7. The percentage of solids showed a somewhat smaller gain indicating that the sugar is formed in part at the expense of other constituents which, however, could not have been starch since the latter in no case varied outside the limits 0.10 to 0.15 per cent. Experiments made the following year brought out no appreciable change in acid during ripening, although fiber and protein decreased slightly whereas wax increased. Results obtained at the end of the period follow:

	Solids	Protein	Wax	Acids as citric	Sugars, total	Fiber
	%	%	%	%	%	%
Early Black	11.5	0.40	0.47	2.86	3.5	1.22
Howes	11.9	0.31	0.35	2.61	3.7	1.47

Changes in Composition during Cold Storage.—Morse,[2] continuing the experiments of Morse and Jones[3] who noted greater losses during ordinary storage than during cold storage, records a small but distinct loss of total sugar and a less pronounced loss of acid during cold storage from November until late Winter or Spring. These losses, often obscured by a gain in solids due to drying, are attributed to respiration. The maximum loss of total sugar was 1.0 per cent and of acid 0.3 per cent.

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[1] Ibid. 1930, Bul. 265, p. 89.

[2] Loc. cit.

[3] Loc. cit.

Acids.—Aparin[1] found in the European cranberry and Kunz and Adam[2] in the foxberry only citric acid. Mach and Portele[3] report in the foxberry, Bigelow and Dunbar,[4] also Nelson,[5] in the American cranberry, *citric* and *malic acids.* Nelson gives the ratio of citric to *l*-malic as 80:20. Stolle[6] found *glyoxylic acid,* reported by others in green fruits, in the European cranberry. Rising[7] states that in addition to citric and malic acids *isovaleric acid* is present.

Loew[8] first called attention to the presence of *benzoic acid* in the foxberry, and later Mach and Portele[3] made quantitative determinations showing 0.066 to 0.086 gram and Schmidt[9] 0.045 to 0.112 gram of benzoic acid per 100 cc. of juice.

According to Griebel[10] the foxberry contains 0.1 per cent of a glucoside *vacciniin* ($C_6H_{11}(C_6H_5CO)O_6$) which is a glucose ester of benzoic acid. He reports the following results: foxberry, free benzoic acid 0.054 to 0.144, total 0.088 to 0.224; European and American cranberries, free benzoic acid 0.011 to 0.041, total 0.021 to 0.061 per cent. Results by Rising[11] on the foxberry show similar amounts of free benzoic acid but higher amounts in combination thus: free benzoic acid 0.092 to 0.104, total (free and combined) 0.246 to 0.315 per cent.

In American cranberries, Mason[12] found 0.05, Bigelow[13] 0.021 to 0.043, Radin[14] 0.06, Nelson[15] 0.069, and Claque and Fellers[16] 0.029 to 0.098 per cent of benzoic acid. The last-named authors observed that a high benzoic acid content is not always indicative of keeping qualities.

Glucosides. *Vacciniin.*—See preceding section.

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[1] Z. Unters. Nahr.-Genussm. 1904, **8**, 254.

[2] Ibid. 1906, **12**, 670.

[3] Landw. Vers.-Stat. 1890, **38**, 69.

[4] J. Ind. Eng. Chem. 1917, **9**, 762.

[5] J. Am. Chem. Soc. 1927, **49**, 1300.

[6] Z. ver. Zuckerind. (N. F.) 1900, **37**, 609.

[7] Kgl. Landtbruks-Akad. handl. Tidskr. 1914, p. 329.

[8] J. prakt. Chem. 1879, **19**, 312.

[9] Z. Unters. Nahr.-Genussm. 1908, **15**, 138.

[10] Ibid. 1910, **19**, 241.

[11] Loc. cit.

[12] J. Am. Chem. Soc. 1905, **27**, 613.

[13] U. S. Dept. Agr., Bur. Chem. 1905, Bul. **90**, 62.

[14] J. Ind. Eng. Chem. 1914, **6**, 518.

[15] Loc. cit.

[16] Plant Physiol. 1934, **9**, 631.

Mineral Constituents.—Goessmann[1] reports a single analysis of the ash as follows: potash 47.96, soda 6.58, lime 18.58, magnesia 6.78, ferric oxide 0.66, phosphoric acid 14.27, and silica 5.22 per cent. Morse[2] gives results on the basis of the fresh fruit as follows: potash 0.068, soda 0.003, lime 0.018, magnesia 0.009, iron 0.00022, manganese 0.00057, phosphoric acid 0.019, sulphur 0.005, and chlorine 0.004 per cent. The alkalinity of the ash was 22 cc. $N/10$ alkali per 100 grams of fruit.

Minor Mineral Constituents. *Iron.*—Berries, 2 samples, 4.0, 4.7 mg. per kilo, fresh basis (Toscani and Reznikoff).[3]

Copper.—Berries 0.9 mg. per kilo, fresh basis (Lindow, Elvehjem, and Peterson).[4]

Iodine.—Berries 0.026 to 0.035 mg. per kilo (Morse).[2]

FOXBERRY

Vaccinium Vitis-Idæa L. = *Vitis-Idæa Vitis-Idæa* Brit.

Fr. Airelle rouge. Sp. Arandano. Ger. Preisselbeere.

Other English names for this berry are mountain cranberry and cowberry. It grows wild in the northern part of the United States as far west as Minnesota and northward into Canada and British Columbia. Large quantities are gathered in Canada both for local use and shipment in barrels with water to the United States. In Germany and Austria the berries are also gathered from wild plants and used for making sauce and preserves.

MACROSCOPIC STRUCTURE.—The *berries* are smaller than the cranberry but are otherwise similar.

MICROSCOPIC STRUCTURE.—Aside from the *outer epiderm* of the spermoderm (Fig. 293) which has a mucilaginous tertiary thickening on outer and inner walls adjoining the lumen, as well as on radial walls, the structure is like that of the cranberry. Whether this distinction holds good for all specimens remains to be decided.

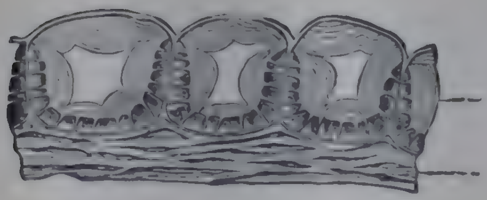

Fig. 293.—Foxberry. Spermoderm in cross section. × 160. (A.L.W.)

Chief Structural Characters.—Noted above.

CHEMICAL COMPOSITION.—Analyses of the whole fruit by Ystgaard[5] and by Rising[6] are in accord with those of the juice given in the subsequent table. Whether the total acid was calculated as citric or malic does not appear, but the difference by the two methods is only four parts in one hundred. The percentages of the individual acids seem low, about 1 per cent being unaccounted for.

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[1] Loc. cit.

[2] J. Biol. Chem. 1929, **81**, 77.

[3] J. Nutrition 1934, **7**, 79.

[4] J. Biol. Chem. 1929, **82**, 465.

[5] Tids. Norske Landwbr. 1902, **9**, 125.

[6] Kgl. Landtbruks-Akad. Handl. Tids. 1914, p. 329.

COMPOSITION OF FOXBERRY

	Samples	Solids	Protein	Acids, total	Citric acid	Malic acid	Sugars	Pentosans	Fiber
		%	%	%	%	%	%	%	%
Ystgaard...	5								
Min......		14.20	.....	1.80	0.62	0.25*	5.70	0.50	....
Max......		17.60	.....	2.00	1.30	0.38*	7.00	0.60	....
Aver.....		**15.48**	**0.25†**	**1.92**	**0.64**	**0.31***	**6.40**	**0.59**	**1.88†**
Rising:									
Min......		.....	.....	2.00	....	.....	7.30	....	....
Max.....		.....	.....	2.20	....	.....	8.30	....	....

* 4 samples. † 1 sample.

In 5 samples of Austrian foxberries Hotter[1] reports the following minimum and maximum results: total solids 15.1 to 17.7, insoluble solids 3.6 to 4.3, extract 12.1 to 14.7, total sugar as invert 6.9 to 10.4, glucose 3.0 to 4.6, fructose 4.0 to 5.8, sucrose 0.4 to 0.8, acid as malic 1.8 to 2.1, tannin 0.17 to 0.33, total ash 0.23 to 0.30, and phosphoric acid 0.03 to 0.04 per cent.

Composition of Foxberry Juice.—A summary of 4 analyses of the juice by Windisch and Schmidt[2] in grams per 100 cc. of the juice appears in the following table:

COMPOSITION OF FOXBERRY JUICE (WINDISCH AND SCHMIDT)

	Sp. gr. 15° C.	Solids	Protein	Acids as citric	Invert sugar	Sucrose	Tannin	Ash, total	Ash, alk.*
Min......	1.038	9.88	0.11	1.71	5.89	0.00	0.17†	0.28	30
Max......	1.049	12.56	0.17	2.10	7.97	0.62	0.20†	0.36	39
Aver.....	**1.043**	**11.28**	**0.12**	**1.92**	6.47	**0.48**	**0.19†**	**0.32**	**34**

* Cc. *N*/10 acid per 100 cc. juice. † 2 samples.

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[1] Z. landw. Versuchsw. 1906, **9**, 747.

[2] Z. Unters. Nahr.-Genussm. 1909, **17**, 584.

Composition of Foxberry Seeds.—Analysis by Diedrichs[1] of the clean air-dry seeds separated from European foxberries gave: water 5.97, protein 23.24, fat 30.12, nitrogen-free extract plus fiber 38.56, and ash 2.11 per cent.

Fatty Oil of Seed.—Diedrichs[2] reports the following values of the drying oil obtained from the seeds: specific gravity at 15° C. 0.9301, refractive index at 25° C. 1.4753, saponification number 190.1, iodine number 169.2, Reichert-Meissel number 0.55, Polenske number 0.30, Hehner number 95.7, acid number 1.94, and hexabromides of linoleic and linolenic acids 22.8 per cent.

Acids.—See Cranberry.

Glucosides.—See Cranberry.

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[1] Z. Unters. Nahr.-Genussm. 1912, **24**, 575.

[2] Loc. cit.

FRUITS OF THE SAPODILLA FAMILY

(*Sapotaceæ*)

Three fruits, the sapodilla, the star apple, and the sapote, are the best-known representatives of the family.

COMPARATIVE MACROSCOPIC STRUCTURE.—The outstanding macroscopic and microscopic character of the family is the presence of chains of *latex sacs* in the mesocarp. These occur also in the cotyledons of the sapote.

The ovary is several-celled but in the fruit not all the cells contain seeds. Characteristic of the seed is the hard outer spermoderm. Endosperm or embryo may be developed one at the expense of the other.

COMPARATIVE MICROSCOPIC STRUCTURE.—In addition to *latex sacs*, the mesocarp of the sapodilla and sapote contain *stone cells* which are lacking in the star apple; the latter, however, has a characteristic gelatinous inner mesocarp about the locules. Stone cells form the outer spermoderm in all the species. Iodine in potassium iodide stains the cell walls of the endosperm of the sapodilla blue. Starch is absent throughout the group.

COMPARATIVE CHEMICAL COMPOSITION.—Fruits of this group are rather insipid owing to the high content of sugar and low acidity.

SAPODILLA

Achras Sapota L. = *Sapota Achras* Mill. = *S. zapotilla* Coville.

Fr. Sapotille. Sp. Zapotillo. It. Sapodilla. Ger. Breiapfel.

Without doubt the sapodilla is the best and most widely distributed of the sapotaceous fruits. It is indigenous to Mexico and Central America. Naseberry is another English name. *Nispero* is a name used in Cuba and Mexico.

Although delicious raw, the fruit does not make satisfactory preserves. Chace, Tolman, and Munson found preserves in glass on sale in Cuba but state that because of the low acidity they were insipid.

The tree also yields, on tapping the bark, latex which, concentrated, is chicle, the chief constituent of chewing gum.

MACROSCOPIC STRUCTURE.—The *flowers* are small, with six hairy sepals, a tubular lobed corolla, six perfect stamens, six staminoides, and an ovary normally with twelve cells, but often with only ten. Commonly the *fruit* (Fig. 294) is ovoid or nearly round, up to more than 8 cm. long, depressed at the base, and with the dried-up sepals attached. Externally it is russet-brown and roughened; on the cut surface light brown with numerous white, hair-like chains of latex sacs evident to the naked eye.

Some or all of the locules are usually empty. When developed, the half anatropous, pendulous *seeds* reach 2 cm. or more in length and are flattened, rounded at one end, blunt-pointed at the other, dark brown excepting the ribbed edge of attachment, extending two-thirds the length, which is light colored. The spermoderm is hard and shell-like, the endosperm bulky, the embryo straight, as long as the endosperm, with exceedingly thin but broad cotyledons and a short radicle.

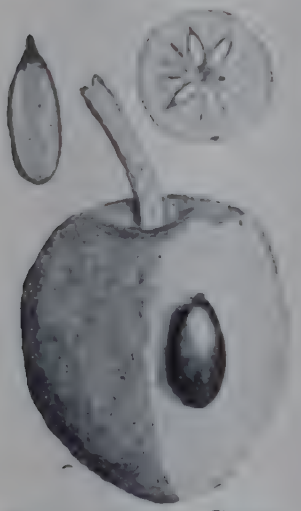

FIG. 294.—Sapodilla. Below: fruit cut to show one seed. ×½. Above: fruit in cross section with three seeds and eight empty locules, ×¼; also seed in section showing thin cotyledons in bulky endosperm, ×1. (A.L.W.)

MICROSCOPIC STRUCTURE. Pericarp (Fig. 295).—The tissues are: (1) *epicarp*, disorganized in the mature fruit; (2) *hypoderm* (*hy*) of cork-like cells with thickened walls and the inner ones with dark contents; (3) *outer mesocarp* (*mes*) of thin-walled cells, some of the smaller with single crystals and some with red-brown contents (*x*); (4) *inner mesocarp* of porous ground tissue cells (mes^2), chains of latex sacs (*l*), stone cells (*st*), and fibro-vascular bundles; and (5) *endocarp* (*end*) of rounded or nearly rectangular cells with brown contents.

Griebel[1] calls the brown cells of the outer mesocarp tannin cells and notes the presence of tannin bodies.

Spermoderm (Fig. 296, *S*).—There are two forms of tissues: (1) *stone cells* with yellow walls and dark contents forming a bulky zone and (2) compressed *brown parenchyma* with occasional small white stone cells.

Endosperm (Fig. 296, *E*).—The cells form a close tissue with somewhat thickened walls staining blue with iodine in potassium iodide, each cell containing an oily granular mass.

Embryo (Fig. 296, *C*).—The thin-walled cells of the cotyledon contain small aleurone grains.

CHIEF STRUCTURAL CHARACTERS.—Fruit 8 cm., depressed at base russet-brown, externally rough, on cut surface brown, showing late sacs; locules twelve or less, some without seeds. Seed up to 2 cm. lon flattened, brown; spermoderm hard; endosperm bulky; cotyledons th

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[1] Z. Unters. Lebensm. 1928, **55**, 89.

Epicarp obliterated; hypoderm cork-like; outer mesocarp thin-walled with crystals; inner mesocarp with chains of latex sacs, stone cells, and bundles. Spermoderm with outer stone cell layer. Endosperm with thick walls staining blue with iodine in potassium iodide. Embryo with small aleurone grains.

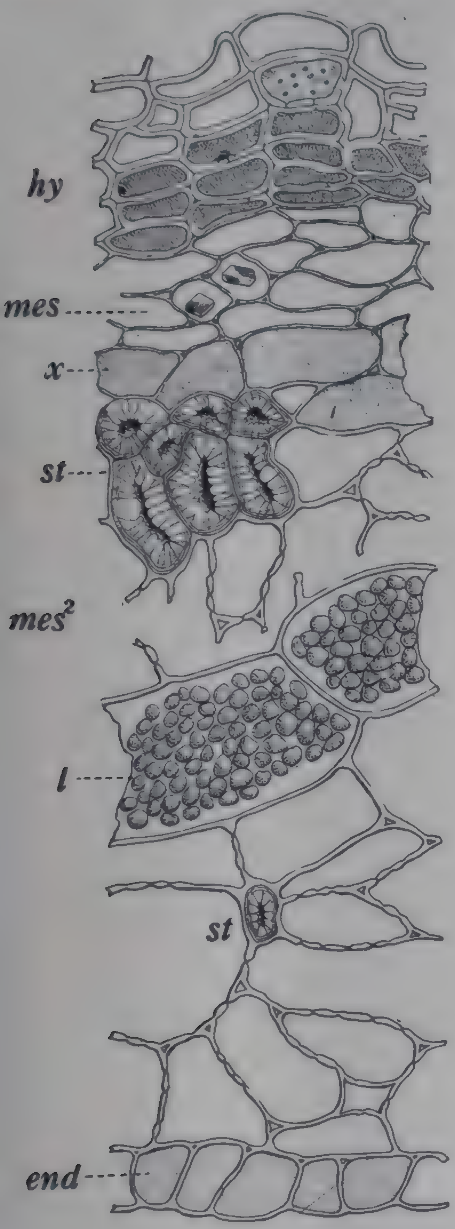

FIG. 295.

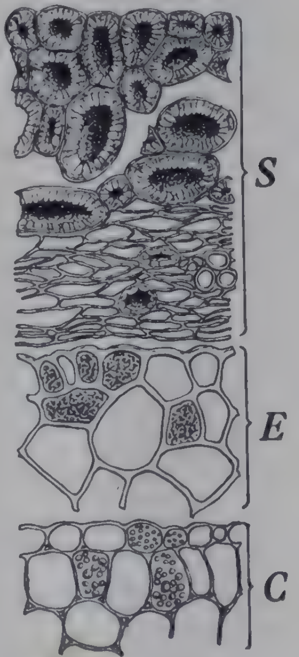

FIG. 296.

FIG. 295.—Sapodilla. Pericarp in cross section. *hy* hypoderm; *mes* outer mesocarp with crystal cells and *x* brown cells; *mes*² inner mesocarp of porous ground tissue; *st* stone cells; *l* latex sacs; *end* endocarp. × 160. (K.B.W.)

FIG. 296.—Sapodilla. Seed in cross section. *S* spermoderm of outer stone cells and inner compressed parenchyma. *E* endosperm. *C* cotyledon. × 160. (K.B.W.)

CHEMICAL COMPOSITION.—The individual fruits of 5 samples of Cuban sapodillas (designated sapota), analyzed by Chace, Tolman, and Munson,[1] weighed 34 to 91 grams, and a single sample of Philippine fruit, analyzed by Pratt and Del Rosario,[2] weighed 50 grams. A summary of the percentages of flesh in the fruit and of the individual constituents in the flesh appears in the following table (p. 834).

Phosphorus-Organic Compounds. *Phytin.*—Bagaoisan[3] reports 1.45 per cent, dry basis, in the flesh.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Philippine J. Sci. 1913, **8**, 59.

[3] Philippine Agr. 1932, **21**, 53.

Composition of Sapodilla Flesh

	Flesh in fruit	Solids, total	Solids, insol.	Protein	Acids as malic	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	cc.
Cuban:									
Min.......	71	21.01	8.39†	0.35‡	0.10	7.34	1.90§	0.38	44
Max.......	81	25.47	9.90†	0.65‡	0.27	14.50	2.54§	0.57	53
Aver......	**75**	**22.97**	**9.15†**	**0.47‡**	**0.21**	**10.95**	**2.22§**	**0.51**	**48**
Philippine...	85	27.5	11.2	0.51	0.07	9.38	4.37	0.63	57

* Cc. N/10 acid per 100 grams pulp. † 3 samples. ‡ 4 samples. § 2 samples.

Mineral Constituents.—Chace[1] found 0.50 per cent of ash in Cuban sapodilla and the amounts of mineral constituents in the ash given below:

K_2O	CaO	MgO	P_2O_5	SO_3	Cl
%	%	%	%	%	%
43.13	7.49	2.83	2.74	4.55	17.41

STAR APPLE

Chrysophyllum Cainito L.

Fr. Cainite. Sp. Cainito.

The star apple owes its name to the narrow radiating locules seen on halving the fruit transversely. It is a native of tropical America.

MACROSCOPIC STRUCTURE.—In general characters of flower and fruit, this species resembles the sapote but the *flower* is light purple, five-merous, and the *fruit* is white to purple, smooth, five- to ten-loculed with several of the locules empty.

In cross section (Fig. 297) the fruit flesh is the same color as the skin with numerous hair-like chains of latex sacs as in the sapodilla, excepting the band of tissue bordering the locules which is nearly colorless and gelatinous in texture.

The *seeds*, about 2 cm. long, somewhat flattened, are suspended the locules. They are dark brown and lustrous except the ventral ed which is light buff and rough. The hilum is on the ventral edge o third the distance from the rounded to the pointed end. Cross secti show that the cotyledons are broad as in sapodilla but thicker, t bulk exceeding that of the endosperm.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

MICROSCOPIC STRUCTURE.—The **Pericarp,** up to the gelatinous issue about the locules, differs from that of the sapodilla chiefly in that 1) a well-formed *epicarp* with round to polygonal cells and scattered tomata is present and (2) *stone cells* are absent.

The gelatinous tissue about the locules consists of thin-walled some-vhat radiating elongated pulp cells with very finely granular contents.

An *endocarp* of small characterless cells with colored contents lines he locules.

Spermoderm.—As in sapodilla.

Endosperm.—This is thinner than n the sapodilla and the thinner walls lo not stain blue with iodine in potas-sium iodide. The contents are oil and ormless protein matter.

Embryo.—As in sapodilla.

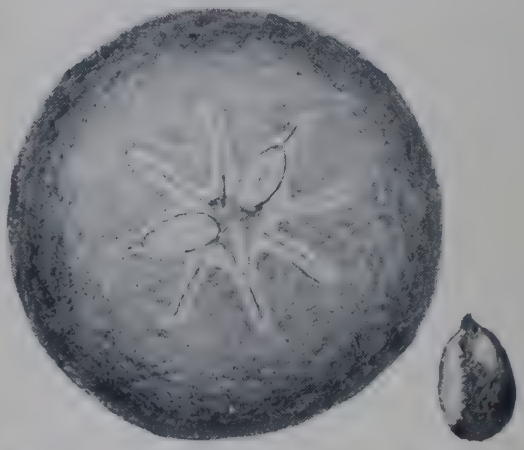

FIG. 297.—Star Apple. Fruit in cross section showing three seeds with cotyledons embedded in endosperm and five empty locules. Below: seed showing the light ventral edge. ×½. (A.L.W.)

CHIEF STRUCTURAL CHARACTERS.—Fruit smooth; inner mesocarp gelati-ous; locules ten or less, some without seeds. Seed up to 2 cm., flattened, brown, pendulous; spermoderm hard; cotyledons bulkier than endosperm.

Epicarp not obliterated; mesocarp without stone cells, about locules thin-walled. Endosperm walls colorless with iodine in potassium iodide. Other characters much as in sapodilla.

CHEMICAL COMPOSITION.—Three analyses by Chace, Tolman, and Munson[1] of the flesh of Cuban star apples, designated purple caimito and white caimito, and a single analysis by Thompson [2] of the flesh of Hawaiian fruit yielded as shown below:

COMPOSITION OF STAR APPLE FLESH

	Flesh in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as malic	Sugars, reducing	Sucrose	Fiber	Ash, total	Ash, alk.*
	%	%	%	%	%	%	%	%	%	%	cc.
Cuban:											
Purple I..	68	15.96	5.54	0.91	....	0.16	6.67	0.26	....	0.44	39
Purple II†	42	14.23	....	0.67	....	0.07	4.01	3.90	....	0.35	33
White....	67	17.19	5.42	0.71	....	0.68	8.27	1.28	....	0.51	46
waiian...	87	11.47	5.46	2.34	1.39	0.17	2.67	1.73	0.86	0.39	..

[1] * Cc. $N/10$ acid per 100 grams pulp. † Weight 208 grams.

[2] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[3] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

Mineral Constituents.—Chace [1] found 0.35 per cent of ash in Cuban star apple and the following amounts of mineral constituents in the ash:

K_2O	CaO	P_2O_5	SO_3	Cl
% 54.75	% 1.31	% 11.00	% 5.50	% 9.46

SAPOTE

Lucuma mammosa Gaertn. = *Calocarpum mammosum* Pierre

Fr. Sapote. Sp. Zapote. It. Sapote.

In Cuba this fruit is called *mamey colorado* and in the Philippines *chico-mamey.* These and similar names cause some confusion, since the true mamey is *Mammea americana.* The tree is indigenous to Central America, but is cultivated in Cuba and throughout the West Indies and also in the Philippines.

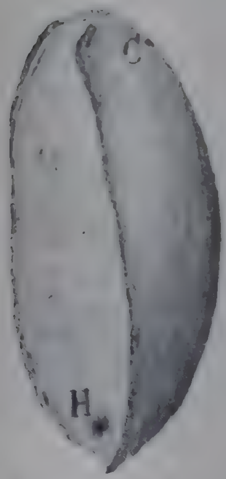

FIG. 298.—Sapote. Whole seed showing dull ventral side with *H* hilum and lustrous dorsal side with *C* chalaza. × ½. (A.L.W.)

Preserves are made from the pulp, and the kernel of the large seed is roasted and used in chocolate.

MACROSCOPIC STRUCTURE.—The white *flowers* have normally a ten-lobed calyx, a five-lobed tubular corolla, five stamens, and a five-celled ovary. The ovoid *fruit* reaches 15 cm. in length. On the surface it is rough, of a russet-brown color; within, it is red or brown with numerous hair-like white chains of latex sacs. Only one *seed* (Fig. 298), which often exceeds 10 cm. in length, commonly develops. On one side it is rounded, glossy, of a buff color; on the other more nearly flat, matt, and of a lighter color. The spermoderm is a woody shell 1 to 2 mm. thick. Excepting a membranous endosperm, the entire kernel consists of the huge cotyledons and the short radicle.

MICROSCOPIC STRUCTURE.—The **Pericarp** and **Spermoderm** differ in structure from those of sapodilla chiefly in the thickness of the layers and minor points such as size of cells and color of contents. The lighter color of the hard spermoderm is due to lighter contents of the stone cells rather than lighter walls.

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. 87, 29.

Endosperm.—This is feebly developed, *aleurone cells* forming only a single row with compressed cells beneath.

Embryo.—The enormous embryo, larger than the meat of any table nut, is developed at the expense of endosperm. The ground tissue is characterless both as to cell form and contents. Starch and well-defined aleurone grains are absent. There are present, however, in the outer half of each cotyledon chains of *latex sacs* like those of the mesocarp.

CHIEF STRUCTURAL CHARACTERS.—Fruit larger than sapodilla. Seed only one, large; spermoderm hard, 2 mm. thick; endosperm thin; embryo very large.

Pericarp and spermoderm with latex sacs and stone cells as in sapodilla. Endosperm with single row of aleurone cells. Embryo characterless except for latex sacs.

CHEMICAL COMPOSITION.—Three analyses by Chace, Tolman, and Munson[1] of the flesh of Cuban sapotes, designated mamey colorado, and one analysis each by Pratt and Del Rosario[2] of the flesh of Philippine sapotes designated Chico mamey, yielded as shown in the following table:

COMPOSITION OF SAPOTE FLESH

	Weight	Flesh in fruit	Solids, total	Solids, insol.	Protein	Acids as citric	Sugars, reducing	Sucrose	Ash, total	Ash, alk.*
	g.	%	%	%	%	%	%	%	%	cc.
Cuban:										
Min. . . .	668†	65	29.24	6.55‡	1.09‡	0.10	5.20	0.29	0.80	56
Max. . .	932†	86	34.01	6.55‡	1.09‡	0.14	20.78	16.85	0.89	64
Aver. . .	**800†**	**75**	**30.99**	**6.55‡**	**1.09‡**	**0.13**	**11.97**	**9.03**	**0.84**	**60**
Philippine	500	70	31.2	9.7	1.23	0.18	8.52	8.00	1.26	119

* Cc. *N*/10 acid per 100 grams pulp. † 2 samples. ‡ 1 sample.

Adriano[3] reports the following results on the flesh constituting 81 per cent of the fruit: solids 15.45, protein 0.60, fat 0.14, fiber 0.81, nitrogen-free extract 13.47, and ash 0.43 per cent.

Fatty Oil of Seed.—Jamieson and McKinney[4] found in the seed 57 per cent of oil. A sample of the oil which had been stored for eight years at 2° C. was examined with the following results:

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**.

[2] Philippine J. Sci. 1913, **8**, 59.

[3] Philippine Agr. 1925, **14**, 57.

[4] Oil & Fat Ind. 1931, **8**, 255.

Physical and Chemical Values.—Specific gravity at 25° C. 0.9105, refractive index at 25° C. 1.4652, saponification number 189.5, iodine number 70.2, Reichert-Meissl number 0.15, Polenske number 0.30, acetyl number 12.2, unsaturated acids 63.73 per cent, saturated acids 30.37 per cent, and unsaponifiable matter 1.39 per cent.

Composition.—As determined by Jamieson and McKinney the oil consisted of:

	%
Glycerides of:	
Arachidic acid	trace
Stearic acid	21.9
Palmitic acid	9.9
Oleic acid	53.4
Linolic acid	13.1
Unsaponifiable matter	1.4
	99.7

Mineral Constituents.—Chace[1] found 0.80 and 0.89 per cent of ash in the flesh of 2 samples of Cuban sapote and the amounts of mineral constituents in the ash shown below:

	K_2O	CaO	MgO	P_2O_5	SO_3	Cl
	%	%	%	%	%	%
I	50.57	1.38	1.36	4.90	3.54	17.34
II	48.20	1.73	3.35	9.66	3.80	16.00

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[1] U. S. Dept. Agr., Bur. Chem. 1904, Bul. **87**, 29.

FRUITS OF THE EBONY FAMILY

(*Ebenaceæ*)

THE kaki or Japanese persimmon and the American persimmon, both species of *Diospyrus*, are here considered. The wild persimmon of China is *D. Lotus* L. which, according to Meyer,[1] yields blackish fruit the size of a cherry much eaten by the natives and on which the kaki is grafted. Among the other species yielding edible fruits are the black sapote or *guayabota* (*D. Ebenaster* Retz.) of Mexico and the *mabolo* (*D. discolor* Willd.) of the Philippines and other parts of Malaysia.

COMPARATIVE MACROSCOPIC STRUCTURE.—The families *Ebenaceæ* and *Sapotaceæ* are closely related, both yielding drupaceous, several-loculed fruits. In the *Ebenaceæ* the spermoderm is leathery (not woody), and the endosperm of the species herewith considered is horny.

COMPARATIVE MICROSCOPIC STRUCTURE.—Characteristic are the *tannin sacs* and the *horny endosperm* with knotty-thickened walls.

COMPARATIVE CHEMICAL COMPOSITION.—Fruits of this group are highly saccharine, the total *sugars* commonly exceeding 15 per cent. The acidity is very low. *Tannin* whether active or inert is a characteristic constituent.

KAKI OR JAPANESE PERSIMMON

Diospyrus Kaki L. f. = *D. chinensis* Blume = *D. Schitse* Bunge. = *D. Roxburghii* Carr.

Fr. Plaquemine. Ger. Kakifeige.

This fruit may be termed the apple of Japan, although it is believed to have originated in China where Meyer[2] found many varieties in cultivation. From Japan, the kaki was introduced into France about one hundred years since and more recently into the southern states and California where, owing to the efforts of Thomas of the U. S. Department of Agriculture at Washington and Hume of Florida, it bids fair to become of great commercial importance.

In Japan, the ripening is hastened by packing the fruit in saki casks.

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[1] U. S. Dept. Agr., Bur. Plant Ind. 1911, Bul. **204**.

[2] Loc. cit.

Gore employs for the same purpose carbon dioxide which is allowed to act on the fruit in closed containers. Dried persimmons are prepared in China and Japan. As sold in the Chinese Quarters of New York, these are white on the surface owing to a film of sugar.

Because of the resemblance of the endosperm, which constitutes the bulk of the seed, to that of the coffee bean, its possible value as a coffee substitute occurred to the writers. Such a substitute, prepared from seed kindly furnished by Mr. Thomas, the persimmon expert of the Bureau of Plant Industry, was found on roasting, grinding, and boiling with water to yield a pleasant-flavored beverage. Naturally, with the present limited production, this observation is not of immediate importance.

MACROSCOPIC STRUCTURE.—Although usually diœcious, the kaki may be polygamous or have perfect, staminate, and pistillate *flowers* on the same tree. Commonly the calyx and corolla are four-lobed and the ovary is four-loculed, each locule being divided by a false partition. On ripening, the calyx lobes persist; excepting these, the reddish orange *fruit* (Fig. 299) resembles the tomato in size and variety of form. In some varieties the breadth exceeds the length, in others the reverse is true. In the latter case the apex may be much narrower than the base, with or without a point.

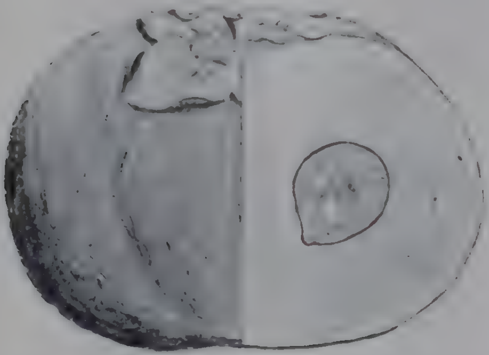

Fig. 299.—Kaki. Fruit with four-lobed calyx at base. Fruit flesh, spermoderm, horny endosperm, and minute embryo are shown in longitudinal section. ×½. (A.L.W.)

Many common varieties, as stated by Hume, are seedless, in which case the fruit flesh is light colored (yellow-orange) and astringent until the pulp on ripening becomes soft and creamy. Other varieties have seeds, the flesh being either light colored and when hard astringent or dark orange-red and in all stages non-astringent. Some of the segments may be of one kind, others of the other.

The light brown *seeds* (Fig. 299) are pendulous, flattened, blunt-pointed, the small embryo being embedded in the horny endosperm at the pointed end.

MICROSCOPIC STRUCTURE.—Aso,[1] Howard,[2] and Lloyd[3] have confined their attention largely to the tannin sacs and the surrounding tissues. Tichomirow,[4] Hanausek,[5] and Griebel[6] refer to the tannin substance under the name of *Inklusen* (inclusions).

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[1] Bot. Mag. Tokyo 1900, **14**, 179.

[2] Bul. Tor. Bot. Club 1906, **33**, 567.

[3] Plant World 1911, **14**, 1.

[4] Compt. rend. 1904, **139**, 305.

[5] B. deut. bot. Ges. 1914, **32**, 117.

[6] Z. Unters. Lebensm. 1927, **53**, 525.

Pericarp (Fig. 300).—The fruit tissues may be described as forming five layers: (1) *epicarp* (*epi*) of cells with greatly thickened outer walls but no stomata; (2) *hypoderm* (*hy*) of small, thin-walled cells; (3) *outer mesocarp* (mes^1) consisting of groups of thick-walled stone cells (*st*), separated by parenchyma, forming a narrow zone; (4) *inner mesocarp* (mes^2), constituting the bulk of the fruit and consisting of large rounded parenchyma cells, those adjoining the endocarp radially elongated, among which are distributed more or less longitudinally elongated (often irregular) tannin sacs (*tan*) and delicate fibro-vascular bundles; and (5) *endocarp* (*end*), of a single row of cells, with walls even thicker than those of the epicarp, which in surface view are seen to be transversely elongated and porous.

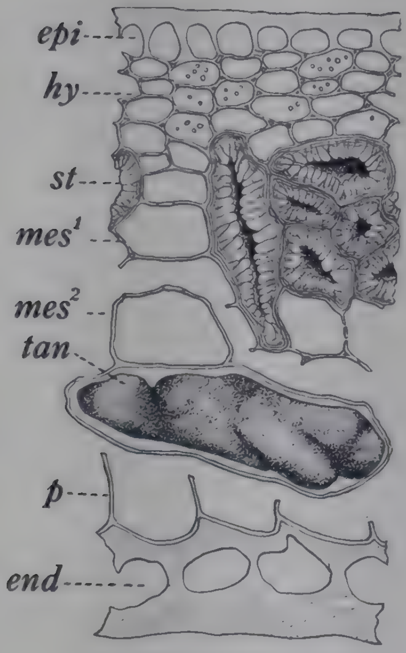

FIG. 300.

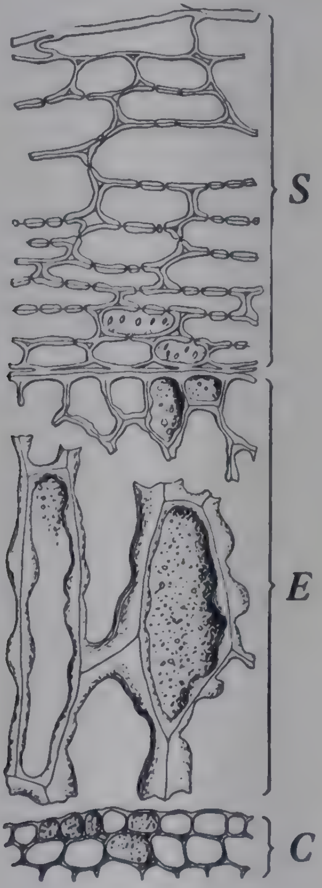

FIG. 301.

FIG. 300.—Kaki. Pericarp in longitudinal section. *epi* epicarp; *hy* hypoderm; mes^1 outer mesocarp with *st* stone cells; mes^2 inner mesocarp with *tan* tannin sac and *p* inner radiating parenchyma; *end* endocarp. × 160. (K.B.W.)

FIG. 301.—Kaki. Seed in cross section. *S* spermoderm; *E* outer and middle endosperm; *C* cotyledon. × 160. (K.B.W.)

The characteristic histological elements are the *tannin sacs*, or cells, with contents similar to those of the carob bean, the date, and the banana, although in the last-named fruit the form and arrangement of the cells are quite different. These cells by reason of their longitudinal elongation, as well as their contents, are readily distinguished from the surrounding parenchyma, even when the walls are indistinguishable in thickness. In certain varieties, however, which in all cases that have come under our observation are not astringent even when hard, the walls of the tannin sacs show marked thickening and distinct pores, although not sclerenchymatized since they stain blue with chlorzinc iodine. On the other hand, it is true that in some varieties, which are non-astringent while still hard, the cell walls are thin, which shows that the thickness of the wall is not the sole factor in determining astringency, if indeed this character is ever more than a coincidence in non-astringent fruits.

Howard rightly observes that in the American persimmon the tannin sacs are smaller than in the Japanese persimmon. He also found that in specimens which came to him under the name of Chinese persimmons the sacs were smaller. In view of the lack of evidence of a definite specific difference between the Japanese and Chinese varieties, it is doubtful whether a distinction based on the size of the tannin sacs will hold.

Howard further advances the theory that the tannin substance in early stages of development is distributed through the parenchyma in soluble form and in later stages collects in the tannin sacs and hardens. That the hardened substance is thus localized is easily demonstrated, but when the tannin is in solution and flows readily from out of cut or injured cells into the surrounding tissues it is indeed difficult to determine its location in the tissues when intact, as noted by Lloyd.

Spermoderm (Fig. 301, *S*).—The cell walls throughout are of a bright yellow-brown color and more or less distinctly beaded. The *outer epiderm* and underlying cells are longitudinally elongated. The radial walls of the outer epiderm, as seen in cross section, are short and the outer walls and cuticle are not greatly thickened, thus distinguishing this species from the American persimmon. The *inner epiderm* has smaller cells than the outer epiderm, similar to the adjoining cells of the middle layer.

Endosperm (Fig. 301, *E*).—As in the coffee bean, date stone, and vegetable ivory the carbohydrate reserve material is largely in the cell walls which show strong, often knotty thickenings. This thickening is particularly marked in the inner portion where the cells are also radially elongated.

Embryo.—*Cotyledons* (Fig. 301, *C*) and *radicle* are made up of small thin-walled cells with finely granular contents.

CHIEF STRUCTURAL CHARACTERS.—Fruit larger than American persimmon, calyx four-lobed; fruit flesh light (orange and astringent when immature) and locules with or without seeds or else fruit flesh dark (red-orange and non-astringent when immature) and one or more seeds always present. Seeds flattened, pointed, with horny endosperm and minute straight embryo.

Outer mesocarp with stone cell groups; inner mesocarp containing tannin sacs with thin or thick porous walls. Outer epiderm of spermoderm with short radial walls and moderately thickened outer wall and cuticle. Endosperm with reserve material in knotty thickened walls. Embryo characterless.

CHEMICAL COMPOSITION.—The analyses in the table below are of the fruit flesh (edible portion) of the fruit. Five of the analyses were reported by McBryde,[1] 5 by Jaffa,[2] and 7, before storage, by Bigelow, Gore, and Howard[3] and also Gore.[4] McBryde's fruits weighed 103 to 194 grams and all were seedless but one which contained 1.7 per cent of seed. Jaffa's samples contained 18.8 to 30.7 per cent of seed. Bigelow, Gore, and Howard report the weight and percentage of seeds in two of their samples as being 137.7 and 86.1 grams and 1.0 and 2.9 per cent respectively.

COMPOSITION OF KAKI FLESH

	Solids	Marc	Protein	Fat	N-f. ext.	Acids*	Sugars, reducing	Tannin	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%
McBryde:										
Min......	23.74	....	0.42	22.69		0.10	15.67	....	....	0.45
Max......	29.83	....	1.10	27.58		0.16	17.83	....	....	1.15
Aver......	**26.67**	....	**0.73**	**25.20**		**0.13**	**16.58**	....	....	**0.74**
Jaffa:										
Min......	18.07	....	1.16	0.31	....	....	12.81	....	0.93	0.61
Max......	22.96	....	1.61	0.85	....	....	19.39	....	2.93	0.72
Aver......	**19.79**	....	**1.36**	**0.57**	....	....	**15.13**	....	**2.08**	**0.68**
B. G. and H.†										
Min......	18.52	3.45	0.40	....	....	0.14‡	14.52	0.13	....	0.39
Max......	25.06	5.29	0.73	....	....	0.15‡	17.75	1.54	....	0.49
Aver......	**21.54**	**3.99**	**0.57**	....	....	**0.14‡**	**15.51**	**0.77**	....	**0.45**

* As malic. † Also Gore. ‡ 2 samples.

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[1] Tennessee Agr. Exp. Sta. 1898, **11**, 220.

[2] U. S. Dept. Agr., Off. Exp. Sta. 1903, Bul. **132**.

[3] J. Am. Chem. Soc. 1906, **28**, 688.

[4] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **141**.

One variety each of non-astringent and astringent kakis gave the following results in the hands of Komatsu and Ueda:[1]

	Water	Protein	Fat	N-f. ext.	Fiber*	Ash
	%	%	%	%	%	%
Non-astringent..........	82.03	0.61	0.02	13.62	3.29	0.43
Astringent..............	93.65	0.58	0.02	12.56	2.76	0.43

* Includes seeds.

Both varieties, whether ripe or green, and regardless of the season, contained dextrose, levulose, sucrose, tannin (kakishibu), pectin, and polysaccharides.

Persimmons grown on the border of the Black Sea, analyzed by Zaretskiĭ,[2] contained: solids 20.3, protein 3.13, invert sugar 15.8, dextrose 3.57, levulose 9.23, acidity 0.1, pentosans 0.67, pectins 0.59, cellulose 0.51, tannin 0.25, and ash 0.46 per cent.

Changes in Composition during Growth, Ripening, and Storage.—Two varieties of kaki, which Bigelow, Gore, and Howard[3] found to contain 0.68 and 0.34 per cent of *tannin* when picked on October 26, after storage 25 and 14 days respectively, contained only traces. During storage the *solids* and *reducing sugars* increased in about the same proportion as a result of drying. In one case the *acid* increased, in the other decreased, during storage.

Gerber[4] advanced the theory, based on his results, that the *tannin* of the kaki, as well as of other astringent fruits, is destroyed by oxidation with the formation of carbon dioxide.

Lloyd[5] held that the *tannin* combines with a carrier independent of protoplasmic activity. The evidence obtained indicates that the cell walls contain *pectocellulose* which digests during ripening.

Contino[6] found that the pulp and skin of kakis when mature contained respectively 0.493 and 0.346 per cent of *tannin* soluble in water but when mellow only 0.200 and 0.034 per cent. The water-insoluble residue of both pulp and skin contained about 0.03 per cent of tannin both before and after mellowing. Since fruit coated with paraffin contained no tannin after storage for a month, he concluded that the change was due to internal conditions and not oxidation. In the paraffined fruit, however, the *pectin* reached 0.53 per cent, but in the uncoated fruit only 0.20 per cent, this gain in the author's opinion being at the expense of tannin.

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[1] J. Biochem. Japan 1922, **1**, 181.

[2] Vsesoyuznui Inst. Rastenievodstva 1934, p. 9; Chem. Abs. 1934, **28**, 6211.

[3] Loc. cit.

[4] Ann. sci. nat. 1896, [8], **4**, 1.

[5] Plant World 1911, **14**, 1.

[6] Staz. sper. agr. ital. 1912, **45**, 460.

Tokugawa [1] attributes the loss of astringency on storage to the hardening of the *gelatinous tannin* substance so that it is not soluble in saliva. Kumagai and Tazaki [2] also hold that the tannin becomes insoluble and does not decompose during storage or processing. On long boiling most of the insoluble tannin dissolves. *Reducing sugars* but no sucrose are present, none of which combines with the tannin. The loss of astringency is accompanied by a slight loss of sugar.

On the other hand Komatsu and Ueda [3] observed in the astringent fruit during ripening an increase in *reducing sugars* at the expense of *sucrose* or *pectin* and of *pentosans* but a decrease in *hexosans* and *soluble tannin*, the latter without forming insoluble compounds with pectin or other substances. The brown color of *pectin* and *cellulose* prepared from the mature fruit is believed to be due to tannin. During the curing of astringent fruit and the ripening of non-astringent fruit soluble tannin disappears and reducing sugar decreases with an increase in *levulose* in the dextrose-levulose ratio. Komatsu and Ishimasa,[4] however, hold that it is essential to have *reducing sugar* sufficient to overcome the disagreeable taste due to acids and tannin. An increase of *nitrogenous substances* was noted in astringent fruit but a decrease in non-astringent.

Komatsu and Ishimasa [5] isolated sucrose from kaki pulp.

Bottini [6] returned to the enzymic theory of Gerber, explaining the disappearance of *tannin* as being due to combustion through the agency of oxidizing enzymes. The fact that practically no tannin remained after storage at both room temperature (17 to 18° C.) and near freezing (1 to 2° C.), but that the red color did not form at the low temperatures, led to the conclusion that the pigment is not formed from tannin but by a condensing diastase. In fruit ripened at room temperature, the *reducing sugar* increased from 8.85 to 10.25 per cent and the *pectin* to 1.2 per cent, whereas at 1 to 2° C. the reducing sugar increased to 9.80 per cent. and the pectin was 0.27 per cent.

Astringent varieties were shown by Davis and Church [7] to increase more in solids, total sugars, and color than the non-astringent, but the latter were richer in sugars, soluble solids, and moisture and contained slightly less acid. In cases where the changes proceed slowly on the tree, most of these, excepting astringency, continue during storage at ordinary temperatures. Ethylene in low concentration hastens ripening and the decrease in astringency.

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[1] Bot. Mag. Tôkyô, 1919, **33**, 1.

[2] J. Sci. Agr. Soc. Japan 1922, **236**, 347.

[3] J. Biochem. Japan 1923, **2**, 291, 309.

[4] Ibid. 1924, **3**, 261.

[5] Mem. Col. Sci. Kyoto Imp. Univ. 1924, **7**, 165.

[6] Ann. chim. applicata 1927, **17**, 415.

[7] J. Agr. Res. 1931, **42**, 165.

Respiration.—Gore,[1] operating with 2 varieties of kakis, noted a maximum evolution of 44 mg. of carbon dioxide per kilo per hour at 35.6° C. and a minimum of 2 mg. at 2.8° C.

Carbohydrates.—See also preceding sections.

As determined by Leoncini,[2] reducing sugars reached a maximum of 59.6 per cent calculated to the dry pulp. A soluble carbohydrate believed to be *mannan*, yielding reducing sugar on hydrolysis with acid at 68 to 72° C., was found in large amount in the fruit of seedless varieties, in smaller amount in varieties with perfect seeds. Loew and Ishii[3] and Ishii[4] had previously isolated mannan from the seed.

Tannin.—See also Changes in Composition during Growth, Ripening, and Storage.

Clark,[5] on hydrolysis of the tannin bodies by weak acid or alkali, obtained tannin, phloroglucinol, and insoluble colloidal matter, apparently a cellulose, but no hexose or pentose.

Griebel[6] found that the contents of the tannin cells yield on hydrolysis with potassium hydroxide, gallic acid, phloroglucinol, and pyrocatechol.

Phosphorus-Organic Compounds. *Phytin.*—In the flesh of *D. discolor* Bagaoisan[7] found 3.26 per cent, dry basis.

Colors.—Leoncini[8] states that the color of ripe Japanese persimmons is due to the condensation and oxidation of tannin substances. The colorless juice of unripe fruit becomes red in ten to twelve days even after heating at 100° C. for 10 minutes.

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[1] U. S. Dept. Agr., Bur. Chem. 1911, Bul. **142**.

[2] Boll. ist. super. agr. Pisa, 1930, **6**, 525.

[3] Landw. Vers.-Stat. 1895, **45**, 535.

[4] Bul. Tokyo Imp. Univ. 1894/7, **2**, 101.

[5] Biochem. Bul. 1913/4, **2**, 412.

[6] Loc. cit.

[7] Philippine Agr. 1932, **21**, 53.

[8] Boll. ist. super. agr. Pisa 1932, **8**, 630.

AMERICAN PERSIMMON

Diospyrus virginiana L.

Fr. Persimon. It. Persimmone. Ger. Virginische Dattelpflaume.

The range of this species is wider than that of the oriental persimmon, wild trees growing as far north as, but not fruiting in, southern New England. Owing to the astringency when hard the fruit is not eaten until it becomes exceedingly soft, some varieties even then remaining inedible.

MACROSCOPIC STRUCTURE.—The fruit is practically the same as that of the kaki, except that it is smaller, up to about 3.5 cm. long; the seeds, however, are fully as large as or even larger than those of the kaki.

MICROSCOPIC STRUCTURE.—Compared with the kaki, the *stone cells* of the outer mesocarp are less strongly developed, the *tannin sacs* of the inner mesocarp, as noted by Howard,[1] are smaller, and, as appears in Fig. 302, the *outer epidermal cells* of the spermoderm have much longer radial walls and thicker outer walls and cuticle.

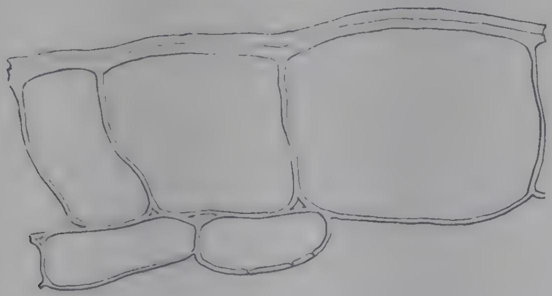

FIG. 302.—American Persimmon. Outer epiderm of spermoderm and two subepidermal cells in cross section. × 160. (K.B.W.)

CHIEF STRUCTURAL CHARACTERS.—As noted above.

CHEMICAL COMPOSITION.—The summary of analyses of the fruit flesh given in the table below represents 1 analysis by Parsons,[2] 6 by Huston and Barrett,[3] 3 by McBryde,[4] and 3 by Bigelow, Gore, and Howard,[5] each for a different tree. So far as determined, the fruit weighed 5.9 to 20.5 grams and contained 9 to 21 per cent of seeds. Analyses made at earlier and later dates showed in general a progressive decrease in acids and tannin and increase in reducing sugars.

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[1] Bul. Tor. Bot. Club 1906, **33**, 567.

[2] Am. Chem. J. 1888, **10**, 488.

[3] Indiana Agr. Exp. Sta. 1896, Bul. **60**, 51.

[4] Tennessee Agr. Exp. Sta. 1898, **11**, 220.

[5] J. Am. Chem. Soc. 1906, **28**, 688.

COMPOSITION OF AMERICAN PERSIMMON FLESH

	Solids	Marc	Protein	Protein pure	Fat	N-f. ext.	Acids as malic	Sugars, reducing	Tannin	Fiber	Ash
	%	%	%	%	%	%	%	%	%	%	%
Parsons...	33.88	....	0.83	....	0.70	29.71	0.00	13.54*	....	1.78	0.86
H. and B.:											
Min....	28.92	....	0.62	0.48	0.16	25.54	....	.....	....	1.02	0.63
Max....	48.21	....	1.21	0.98	0.42	43.88	....	.....	....	1.83	1.04
Aver....	**35.84**	....	....	**0.75**	**0.32**	**31.76**	....	.....	....	**1.43**	**0.78**
McBryde:											
Min.....	33.22	....	0.48	....	31.32		0.15	18.72	....	....	0.84
Max....	42.76	....	0.64	....	41.34		0.26	23.50	....	....	1.28
Aver....	**39.58**	....	**0.57**	....	**37.88**		**0.19**	**21.90**	....	....	**1.13**
B. et al.:											
Oct. 13.	27.26	5.45	1.08	....	....	.....	0.49	16.31	2.14†	....	0.77
Sept. 13.	29.61	6.48	0.84	....	....	.....	0.37	18.05	1.98†	....	0.65
Oct. 4.	23.62	4.38	0.46	....	....	.....	0.33	14.67	2.47†	....	0.62

* Sucrose 1.03%. † After storage 5 to 8 days, trace.

Mineral Constituents.—Analyses by Troop and Hadley[1] of the ash of the pulp and of the seed, recalculated in the former case free of 15.94 per cent of carbon dioxide and 4.32 per cent of water and in the latter case free of 2.52 per cent of water, follow:

	K_2O	Na_2O	CaO	MgO	Fe_2O_3	Mn_2O_3	P_2O_5	SO_3	SiO_2	Cl
	%	%	%	%	%	%	%	%	%	%
Pulp.	67.13	2.95	5.95	2.79	0.66	0.08	9.12	8.59	1.80	0.38
Seed.	38.60	0.84	6.93	7.13	1.22	0.10	13.71	10.80	20.62	0.11

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[1] Indiana Agr. Exp. Sta. 1896, Bul. **60**, p. 43.

FRUITS OF THE DOGBANE FAMILY

(*Apocynaceæ*)

SEVERAL species of *Carissa*, valuable also as thorny hedge plants, yield edible fruits of which the amatungula, described below, is of importance in South Africa.

COMPARATIVE MACROSCOPIC STRUCTURE.—Fruit plum-like, with milky juice.

COMPARATIVE MICROSCOPIC STRUCTURE.—The outstanding features are the branching latex tubes of the edible pulp and the outer epidermal cells of the spermoderm extended as remarkable reticulated, hair-like papillæ.

AMATUNGULA

Carissa grandiflora DC. = *Arduina grandiflora* E. Mey.

Like the kei apple, several species of *Carissa* are thorny shrubs valuable for hedges and for the edible fruits. The amatungula, or Natal plum, is a native of the coastal region of South Africa where the fruit of wild shrubs and hedges is a favorite both with aborigines and Europeans during the rainy season. It is eaten raw and made into jams and jellies, but the sticky juice on hands and utensils is annoying, necessitating removal with lemon juice. The flavor on cooking is said to resemble that of the cranberry.

Fruit for study from Durban, Natal, and details as to its use were kindly furnished through the courtesy of Mrs. Fred Bunker and Mrs. A. E. LeRoy.

Other species of *Carissa*, yielding edible fruits smaller than the amatungula, are *C. bispinosa* Desf. (*C. Arduina* Lam.), a native of South Africa, *C. Carandas* L., a native of India, and *C. edulis* Vahl., a native of tropical Africa. Several of the species have been introduced into California, Florida, and Hawaii.

MACROSCOPIC STRUCTURE.—The *flowers* have a five-lobed calyx, a tubular corolla with five spreading lobes (10 cm.), five stamens, and a two-celled superior ovary. The *fruit* is red, plum-like, varies up to 5 cm. in length, and has a pink milky fruit flesh with thread-like latex tubes evident to the naked eye. Each of the two locules contains one or more flattened-oval, margined *seeds* up to 7 mm. long, with a bulky endosperm and small straight central embryo.

MICROSCOPIC STRUCTURE. Pericarp.—This consists of (1) *epicarp* of polygonal cells, with rather thick walls and finely granular contents, and stomata; (2) *hypoderm* of cells like the mesocarp but with deeper red contents; (3) *mesocarp* of typical rounded pulp cells with reddish contents and numerous, especially in the inner part, large branching latex tubes; and (4) *endocarp* of thin-walled cells and large stomata.

The *latex tubes* are the conspicuous elements.

Spermoderm (Fig. 303).—On the body of the seed only one layer, the outer *epiderm* (*aep*), shows cell structure, but at the edges one or more rows of characterless, thin-walled cells (*p*) also are evident. The yellow-brown epiderm is remarkable for the greatly thickened porous radial walls and the extension of the cells into thinner-walled reticulated papillæ. The total length of cell proper and papilla reaches 300 μ or more, but on the sides of the seed the cell proper is very low and the papilla correspondingly long while on the edge of the seed the cell proper makes up more than one-half the total. The inner walls also show large pores.

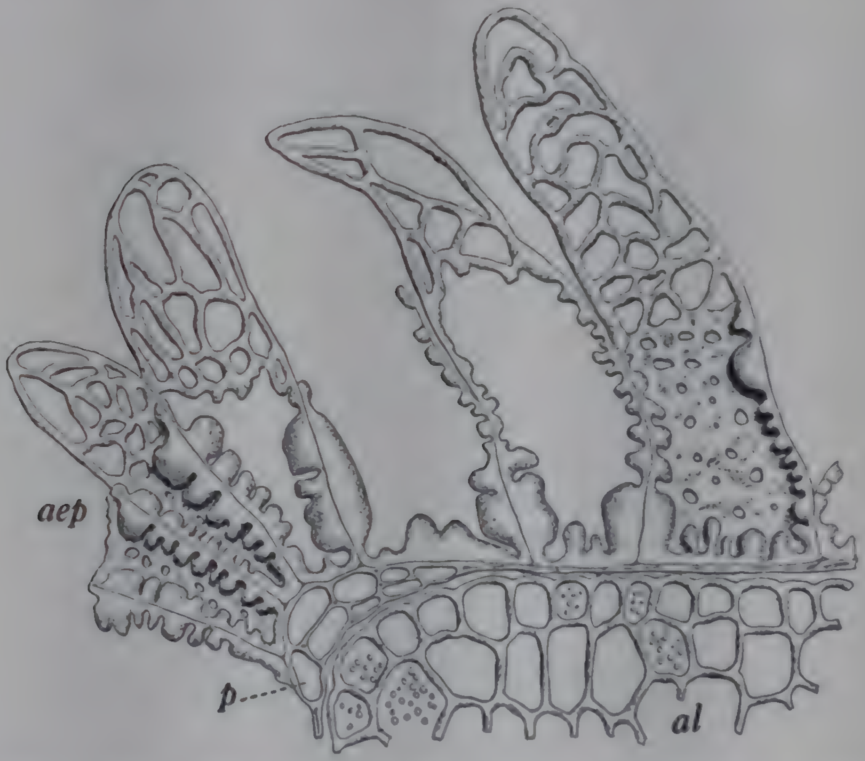

FIG. 303.—Amatungula. Seed in cross section through edge. Spermoderm: *aep* outer epiderm, *p* parenchyma, collapsed except over the edge of seed. Endosperm with *al* aleurone cells. × 160. (K.B.W.)

Endosperm (Fig. 303).—The cells are typical *aleurone cells* (*al*) with aleurone grains up to 12 μ, each with numerous small but distinct globoids.

Embryo.—The small cells of the thin cotyledons contain fat and small aleurone grains.

CHIEF STRUCTURAL CHARACTERS.—Fruit plum-like; locules two. Seeds several, flattened, oval, margined; endosperm bulky; embryo small.

Pericarp with numerous latex tubes. Epidermal cells of spermoderm with thickened porous walls, extended as reticulated papillæ. Endosperm with aleurone grains up to 12 μ containing numerous globoids.

CHEMICAL COMPOSITION.—A single analysis by Thompson[1] of a sample grown in Hawaii is given below:

COMPOSITION OF AMATUNGULA FLESH (THOMPSON)

Flesh in fruit	Solids, total	Solids, insol.	Protein	Fat	Acids as malic*	Sugars, reducing	Sucrose	Fiber	Ash
%	%	%	%	%	%	%	%	%	%
78	21.55	4.29	0.56	1.03	1.71	12.00	0.00	0.92	0.44

* In the absence of data the acid is tentatively calculated as malic.

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[1] Hawaii Agr. Exp. Sta. Rep. 1914, p. 62.

FRUITS OF THE MADDER FAMILY

(*Rubiaceæ*)

To THIS family belong coffee and the bed straws (*Galium*). The genipap is the most important succulent fruit.

GENIPAP

Genipa americana L.

This fruit is a native of the West Indies and neighboring regions of South America. In Puerto Rico it is known as *jagua*. Another name is marmalade-box. When picked the fruit is hard but softens on keeping.

MACROSCOPIC STRUCTURE.—The *flower* (2 to 3 cm.) has a bell-shaped calyx, a salver-shaped, pale yellow corolla, and a one-celled ovary. Characteristics of the *fruit* are its more or less elongated (up to 10 cm. or more) form, russet surface, firm rind (1 cm.), and soft pulp tissue of the two placentæ in which the numerous seeds are embedded.

The anatropous *seeds* are about 1 cm. long, 6 mm. wide, and 2 to 3 mm. thick. Within the thin spermoderm is the bulky endosperm in the center of which is embedded the flattened embryo with broad, ovate cotyledons about equaling the radicle, suggesting the embryo of coffee.

MICROSCOPIC STRUCTURE. Pericarp.—The rind consists of (1) *epicarp* of isodiametric, somewhat wavy-walled cells which in the russet spots have thickened porous walls and brown contents; (2) *hypoderm* of rounded or flattened cells containing chlorophyl grains; (3) *stone cells*, isodiametric or somewhat elongated, with thick walls forming with the separating parenchyma a well-marked zone; (4) *mesocarp* of rounded cells, containing occasional crystal rosettes, through which run the fibro-vascular bundles; and (5) *endocarp* of tangentially elongated, colorless stone cells with lumen often reduced to a mere line.

The *placental tissue* consists of thin-walled, much-elongated parenchyma cells and numerous special cells containing large crystal rosettes.

Spermoderm.—The *outer epiderm* consists of large, longitudinally elongated cells which in surface view appear to have uniformly thick walls. Cross sections show that the thickening is due to a bead-like swelling in the middle of the radial wall. The walls stain yellow with iodine in potassium iodide. A second layer with more than one swelling on the radial walls is present in parts. The remainder of the spermoderm is *compressed parenchyma.*

Endosperm.—The walls are somewhat thickened and stain blue with iodine in potassium iodide. They do not show the knotty appearance characteristic of the corresponding cells of the coffee bean. The contents are small aleurone grains and fat, also occasional small starch grains.

Embryo.—The thin cotyledons are made up of thin-walled parenchyma and procambium bundles.

CHIEF STRUCTURAL CHARACTERS.—Fruit 10 cm. long; rind 1 cm. thick, firm; placental pulp bulky. Seeds numerous, flattened.

Epicarp in russet spots with thickened beaded walls; stone cell zone between hypoderm and mesocarp; mesocarp and placental cells with large crystal rosettes; endocarp of stone cells. Outer epidermal cells of spermoderm longitudinally elongated with radial walls thickened in the middle. Endosperm rather thick-walled containing chiefly aleurone grains and fat.

FRUITS OF THE HONEYSUCKLE FAMILY

(*Caprifoliaceæ*)

Several species of *Sambucus* yield fruit used for cooking and wine making.

ELDERBERRY

Sambucus spp.

Fr. Graine de sureau. Sp. Sambuco. It. Sambuco.
Ger. Holunderbeere.

The structure of the common purple-black berried American elderberry (*S. canadensis* L.) is here described. Chemical data are on the red-berried American species *S. pubens* Michx. (*S. racemosa* var. *pubescens* Dipp.) and the black-berried European species *S. nigra* L.

MACROSCOPIC STRUCTURE.—The *flowers* are white, terminal, in cymes; each *drupelet*, about 7 mm. in diameter, has usually three *stones* with distinct endosperm and embryo.

MICROSCOPIC STRUCTURE. Pericarp.—The layers are (1) *epicarp* of isodiametric, thick-walled, beaded cells with striated cuticle; (2) *mesocarp* of rounded pulp cells and delicate bundles; (3) single layer of small isodiametric, *thin-walled cells*; (4) radially elongated *stone cells*; and (5) crossing sclerenchyma *fibers*, the last three forming the endocarp.

Spermoderm.—A narrow, nearly structureless membrane.

Endosperm and **Embryo.**—Small aleurone grains and fat globules evident.

CHEMICAL COMPOSITION.—No analysis of the common elderberry is at hand, but Hotter[1] reports the following range in the pulp of three Austrian samples of black elderberry:

Composition of Black Elderberry (Hotter)

	Solids, total	Solids, insol.	Extract	Acids as malic	Sugars, total*	Dextrose	Levulose	Tannin	Ash, total†
	%	%	%	%	%	%	%	%	%
Min...	18.1	8.2	10.3	0.9	4.7	2.5	2.1	0.29	0.53
Max..	20.9	9.2	12.1	1.3	5.8	3.0	2.9	0.22	0.79

* As invert. † Phosphoric acid 0.12 to 0.14%.

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[1] Z. landw. Versuchsw. 1906, 9, 747.

Fatty Oil of Seed. *Physical and Chemical Values.*—The following are by Zellner [1] on oil from the seed of *S. razemosa* and by Byers and Hopkins [2] on that from *S. racemosa arborescens* respectively: specific gravity at 15° C. 0.9171, 0.9072; refractive index at 20° C. 1.472, ...; melting point . . . ., 0° C.; saponification number 196.8, 209.3; iodine number 89.5, 81.44; and Reichert-Meissl number 1.8, 1.54.

Constituents.—Calculations of Byers and Hopkins show: *palmitin* 22, *olein* 67.9, *linolein* 5.7, and *caprin*, *caproin*, and *caprylin* 3 per cent. Zellner found a small amount of *arachidin*.

Colors.—From the juice of the European elderberry Karrer and Widmer [3] obtained *sambucin*, a cyanidin rhamnoglucoside. Nolan and Casey [4] from the same source isolated two crystalline pigments, *chrysanthemin* (cyanidin monoglucoside) and *sambucicyanin*, the latter apparently a bimolecular compound of chrysanthemin and a pentose glucoside of cyanine.

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[1] Monatsh. 1902, **23**, 937.

[2] J. Am. Chem. Soc. 1902, **24**, 771.

[3] Helv. Chim. Acta 1927, **10**, 67.

[4] Proc. Roy. Irish Acad. 1928, **38**, 93; 1931, **40**, B, 56.

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